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IV - Semester

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LAB - ADVANCED ELECTRONICS AND PHYSICS

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LAB - ADVANCED ELECTRONICS AND PHYSICS

Syllabi

(Any Fifteen of the following)

1. BCD to 7 Segment Display and BCD Decoder.
2. Shift Register and Ring Counter.
3. Operation of 7489 RAMS.
4. Arithmetic Operations - Microprocessor 8085.
5. Logical Operations - Microprocessor 8085.
6. Code Conversion - Microprocessor 8085.
7. Determination of Plank's Constant using Photocell Apparatus.
8. E/m by Millikan's Oil Drop Method.
9. E/m by Thompson's Oil Drop Method.
10. Thermal Conductivity of a Bad Conductor (Lee's Method).
11. Hydrogen Spectrum and Rydberg's Constant.
12. Determination of BH and m using Magnetometers.
13. Determination of Stefan's Constant.
14. Fabry-Perot Interferometer.
15. Solar Cell Characteristics.
16. Polarizability of Liquids - Hollow Prism - Spectrometer.
17. Determination of Specific Rotatory Power of a Liquid using Polarimeter.
18. Any of the Experiments of Equal Standard.

INTRODUCTION

NOTES

Electronics comprises the physics, engineering, technology and applications that deal with the emission, flow and control of electrons in vacuum and matter. It uses active devices to control electron flow by amplification and rectification, which distinguishes it from classical electrical engineering which uses passive effects, such as resistance, capacitance and inductance to control current flow. Electronics has had a major effect on the development of modern society. The identification of the electron in 1897, along with the subsequent invention of the vacuum tube which could amplify and rectify small electrical signals, inaugurated the field of electronics and the electron age.

An electronic component is any physical entity in an electronic system used to affect the electrons or their associated fields in a manner consistent with the intended function of the electronic system. Due to the complex nature of electronics theory, laboratory experimentation is an important part of the development of electronic devices.

In experimental physics it is required to use electronics as instruments. Experimental physics is the category of disciplines and sub-disciplines in the field of physics that are concerned with the observation of physical phenomena and experiments. Methods vary from discipline to discipline, from simple experiments and observations to more complicated ones. Experimental physics uses two main methods of experimental research, controlled experiments, and natural experiments. Controlled experiments are often used in laboratories as laboratories can offer a controlled environment. Natural experiments are used, for example, in astrophysics when observing celestial objects where control of the variables in effect is impossible.

This lab manual, *Advanced Electronics and Physics*, contains laboratory experiments on BCD to 7 Segment Display and BCD Decoder, Shift Register and Ring Counter, Operation of 7489 RAMS, Arithmetic and Logical operations – Microprocessor 8085, determination of Plank's Constant using Photocell apparatus, E/m by Millikan's and Thompson's method, Thermal Conductivity of a Bad Conductor (Lee's method), Hydrogen Spectrum and Rydberg's Constant, determination of B_H and m using Magnetometers, determination of Stefan's Constant, Fabry-Perot Interferometer, Solar Cell characteristics, Polarizability of liquids (Hollow Prism – Spectrometer), etc. These experiments shall be taken as the base reference during lab activities for students.

7 SEGMENT DISPLAY

NOTES

EXPERIMENT: 1 BCD to 7-Segment Display

AIM:

1. To learn about decoders and its applications.
2. To understand the working of IC 7447

Apparatus Required

IC7447, 7-Segment Display (Common Anode), Patch Chords, Resistor (1K) and Bread Board.

Theory

A decoder is a combinational circuit that is used to decode the information on n input lines to a maximum of 2^n unique output lines. Figures 1 and 2 display the circuit representation and truth table of a 3-to-8 decoder, respectively.

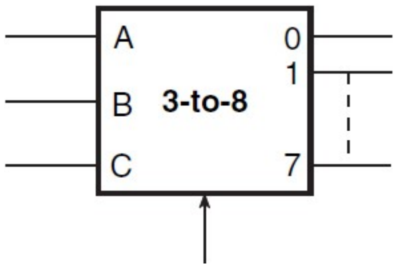


Fig. 1

INPUTS			OUTPUTS							
A	B	C	D_0	D_1	D_2	D_3	D_4	D_5	D_6	D_7
0	0	0	1	0	0	0	0	0	0	0
0	0	1	0	1	0	0	0	0	0	0
0	1	0	0	0	1	0	0	0	0	0
0	1	1	0	0	0	1	0	0	0	0
1	0	0	0	0	0	0	1	0	0	0
1	0	1	0	0	0	0	0	1	0	0
1	1	0	0	0	0	0	0	0	1	0
1	1	1	0	0	0	0	0	0	0	1

Fig. 2

NOTES

3-to-8 decoder can be implemented using 3 NOT and 8 AND gates as shown in Figure 3 below.

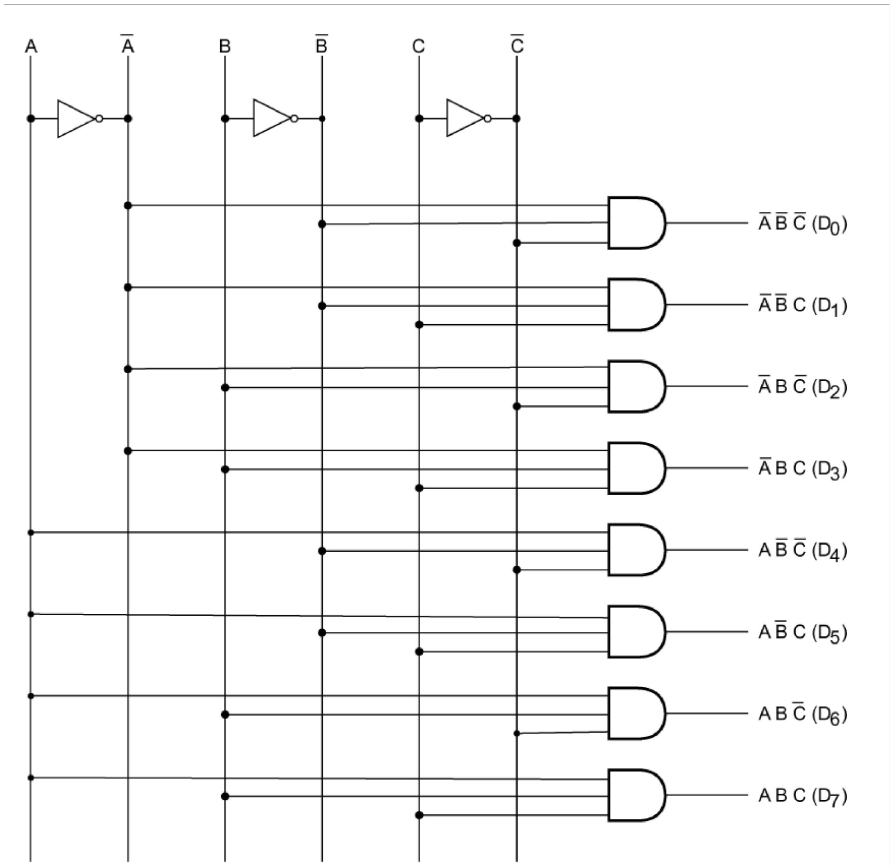


Fig. 3

BCD to 7-Segment Display Decoders

A Binary Coded Decimal (BCD) to 7-segment display decoder consists of 4 BCD inputs and 7 output lines, one for each LED segment. Using this decoder, a smaller 4-bit binary number (half a byte) can be used to display all the numbers from 0 to 9. The IC 7447 and IC 7448 are commonly used for this purpose. The Figure 4 shows the circuit representation of BCD to 7-Segment Decoder.

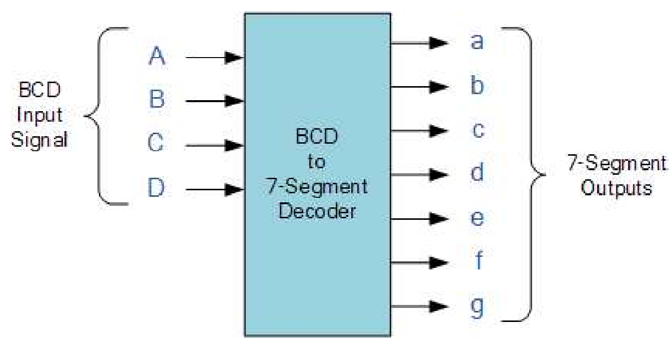


Fig. 4

NOTES

The Light Emitting Diode (LED) is a semiconductor device which finds its place in many applications in this modern electronic fields and one of them is the Seven Segment Display. Seven-segment displays consists of seven individual LED's arranged in 'Eight' (8) shape, and a Dot (.) with a common electrode, lead (Anode or Cathode). The purpose of arranging it in that form is to be able to make any number out of that by switching ON and OFF the particular LED's. Figure 5 gives the block diagram of the Seven Segment LED arrangement.

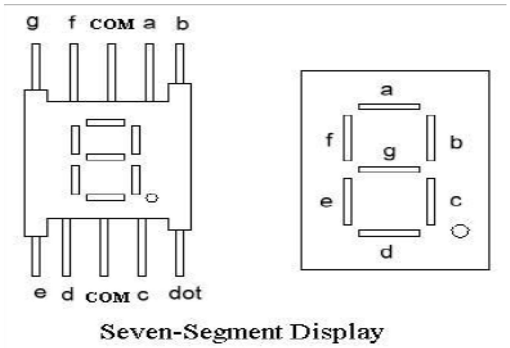


Fig. 5

LED's are basically of following two types:

Common Cathode (CC) - All the 8 anode legs use only one Cathode, which is common. Common Anode (CA) - The common leg for all the cathode is of Anode type.

Circuit Diagram

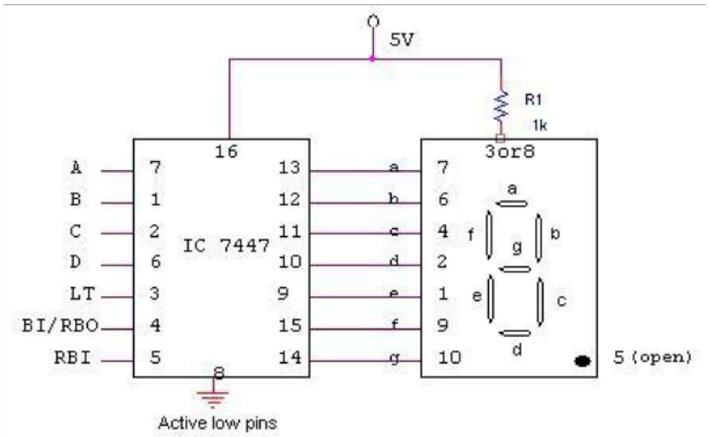


Fig. 6

NOTES

TRUTH TABLE:

BCD Inputs				Output Logic Levels from IC 7447 to 7-segments							Decimal number display
D	C	B	A	a	b	c	d	e	f	g	
0	0	0	0	0	0	0	0	0	0	1	0
0	0	0	1	1	0	0	1	1	1	1	1
0	0	1	0	0	0	1	0	0	1	0	2
0	0	1	1	0	0	0	0	1	1	0	3
0	1	0	0	1	0	0	1	1	0	0	4
0	1	0	1	0	1	0	0	1	0	0	5
0	1	1	0	1	1	0	0	0	0	0	6
0	1	1	1	0	0	0	1	1	1	1	7
1	0	0	0	0	0	0	0	0	0	0	8
1	0	0	1	0	0	0	1	1	0	0	9

Fig. 7

Procedure

1. Check all the components for their working.
2. Insert the IC 7447 into the bread board.
3. Make connections as shown in the circuit diagram.
4. Verify the Truth Table and observe the outputs.

SHIFT REGISTER AND RING COUNTER

EXPERIMENT: 2 Shift Register and Ring Counter

AIM:

1. To realize and study Ring Counter and Johnson Counter
2. To understand the working of IC 7495

Apparatus Required

IC 7495, Patch Cords and IC Trainer Kit.

Theory:

Shift Register

A **Register** is a sequential device, used to store digital information. It is a group of flip flops connected in series, which is used to store multiple bits of data. An n-bit shift register can be constructed by connecting n flip-flops where each flip flop stores a single bit of data. Shift registers are basically of 4 types. These are

1. Serial-In Serial-Out Shift Register
2. Serial-In Parallel-Out Shift Register
3. Parallel-In Serial-Out Shift Register
4. Parallel-In Parallel-Out Shift Register

In this practical, Parallel-In Parallel-Out Shift Register will be realized using IC 7495. This type of shift register also acts as a temporary storage device or as a time delay device similar to the Serial-In-Serial-Out configuration. The data is presented in a parallel format to the parallel input pins P_A to P_D and then transferred simultaneously directly to their respective output pins Q_A to Q_A by the same clock pulse. Further, one clock pulse loads and unloads the register. This arrangement for parallel loading and unloading is shown by the schematic in Figure 1.

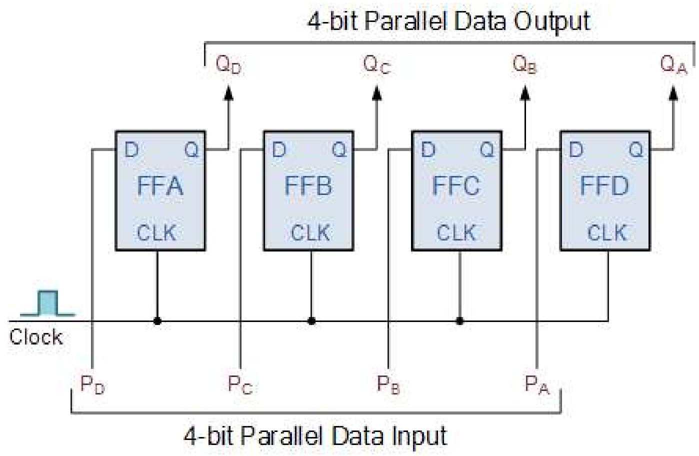


Fig. 1

Circuit Diagram

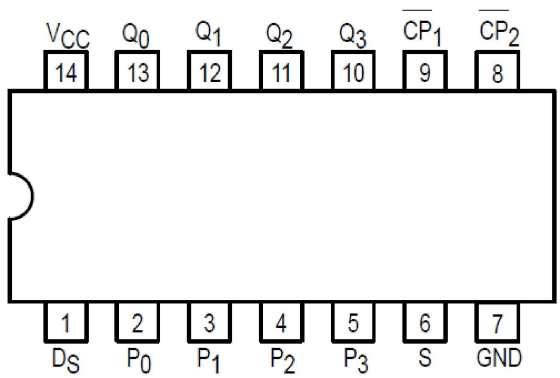


Fig. 2

PIN NAMES

S	Mode Control Input
D_S	Serial Data Input
$P_0 - P_3$	Parallel Data Inputs
$\overline{CP_1}$	Serial Clock (Active LOW Going Edge) Input
$\overline{CP_2}$	Parallel Clock (Active LOW Going Edge) Input
$Q_0 - Q_3$	Parallel Outputs (Note b)

NOTES

Ring Counter

The ring counter is a series of interconnected flip flops, in which the output of last flip flop is connected to input of first flip flop. In a ring counter if the output of any stage is 1, then its reminder is 0. The Ring counters relays the same output throughout the circuit.

That means if the output of the first flip flop is 1, then this is transferred to its next stage i.e. 2nd flip flop. By transferring the output to its next stage, the output of first flip flop becomes 0. And this process continues for all the stages of a ring counter. If we use n flip flops in the ring counter, the '1' is circulated for every n clock cycles.

The implementation of the ring counter using D flip-flops is shown below in Figure 3.

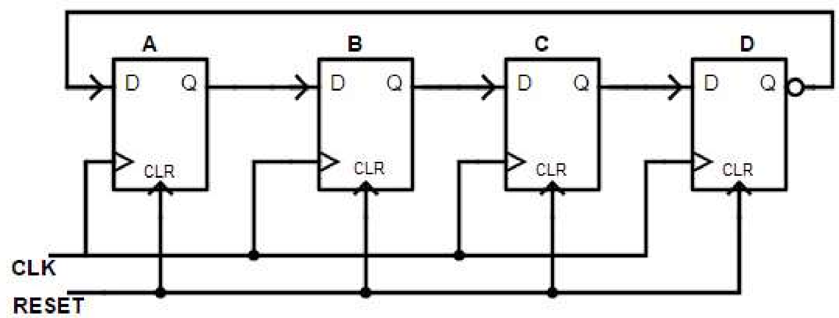


Fig. 3

In this experiment we design the ring counter by using D flip flop. This is a Mod 4 ring counter which consists of 4 D flip flops connected in series. The clock signal is applied to the clock input of every flip flop simultaneously and the RESET pulse is applied to the CLR inputs of all the flip flops.

Operation of Ring Counter

To begin with, all the flip flops in ring counter are reset to 0 by applying CLEAR signal. Before applying the clock pulse, we apply the PRESET pulse to the flip flops which assigns the value '1' to the ring counter circuit. For each clock signal, the data circulates among all the 4 flip flop stages of ring counter. This 4 staged ring counter is called Mod 4 ring counter or 4 bit ring counter. To circulate the data correctly in the ring counter, we must load the counter with required values like all 0's or all 1's.

Truth Table of Ring Counter

The truth table of the 4 -bit ring counter is explained below in Figure 4.

NOTES

Q_0	Q_1	Q_2	Q_3
1	0	0	0
0	1	0	0
0	0	1	0
0	0	0	1

Fig. 4

When CLEAR input CLR = 0, then all flip flops are set to 1. When CLEAR input CLR = 1, the ring counter starts its operation. For one clock signal, the counter starts its operation. On next clock signal, the counter again resets to 0000. Ring counter has 4 sequences: 0001, 0010, 0100, 1000, 000.

Circuit Diagram

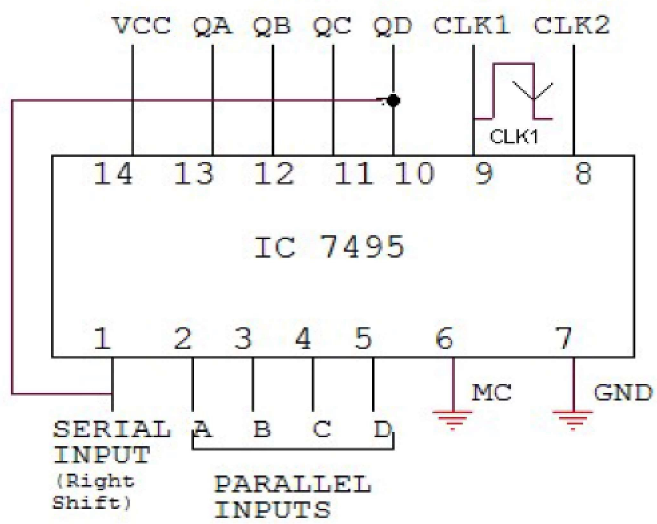


Fig. 5

Procedure

1. Check all the components for their working. ·
2. Insert the appropriate IC into the IC base/bread baord. ·
3. Make connections as shown in the circuit diagram. ·
4. Apply clock to pin number 9 and observe the output for ring counter.

EXPERIMENT:3 Design and Verification of Memory (SRAM) (16×4) – IC 7489

NOTES

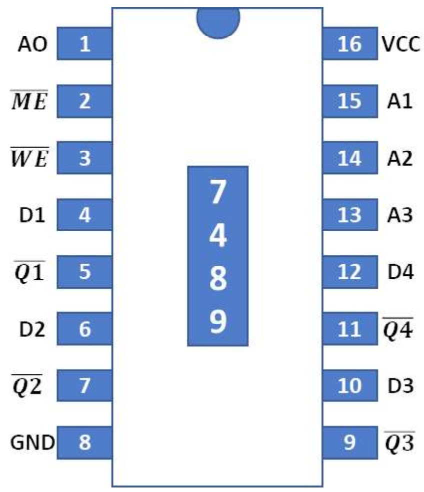
Aim

To study the operation of the RAM IC 7489 and verify the truth table.

Apparatus

Power Supply, RAM IC 7489, LED Output Indicators, Bread Board, Connecting Wires.

Pin Diagram



Operation

The truth table for RAM IC7489 (16 words × 4 bit) Read/Write Memory is given below

Memory Enable	Write Enable	Operation
H	X	All data outputs are high
L	H	Read Mode (Data outputs are compliment of RAM content)
L	L	Write Mode (Data inputs are written on to the memory; Data outputs are compliment of RAM content)

- The memory Enable pin is used to select 1- of -n ICs, i.e., like a Chip Select Signal. For simply city, the memory enable pin is permanently held low.
- The address lines are given through an up /down counter with preset capability.
- The set address switch is held high to allow the user to choose any location in the RAM, using the address bits.

- The address and data bits are used to set an address and enter the data.

- The 'Read/Write 'switch is used to write data on to the RAM.

Procedure

NOTES

This experiment has 3 stages – Clearing the Memory, Data Entry (Write Operation) and Data Verification (Read Operation).

Clearing the Memory: The RAM IC 7489 is a volatile memory. This means that it will lose the data stored in it, on loss of power. However, this does not mean that the content of the memory becomes 0h, but not always. The RAM IC 7489 does not come with a 'Clear Memory' signal.

The memory has to be cleared manually.

1. Position the 'Stack/Queue' switch in the 'Queue' position.
2. Position the 'Set Address' switch in the '1' position.
3. Set the address bits to 0h (first byte in the memory).
4. Position the 'Set Address' switch in the '0' position to disable random access and enable the counter.
5. Position the 'Read/Write' switch in the 'Write' position to write data on to the memory.
6. Set the data bits to 0h (clearing the content).
7. Observe that the LEDs (D4 to D1) glow. This is to indicate that the content is 0h. Refer the truth table above and observe that the data outputs of the RAM will be compliments of the data inputs.
8. Position the 'Increment/Decrement' switch in the 'Increment' position.
9. Press the 'Clock' to increment the counter to the next address. As the 'Read /Write' switch is already in the 'Write' position, and the data bits are set to the 0h, the content in the new location is also replaced with 0h.

Write Operation

1. Assume that the following data has to be written on to the RAM. The address and data are given in the hexadecimal format.
2. Position the 'Stack/Queue' switch in the 'Queue' position.
3. Position the 'Read/Write' switch in the 'Write' position to enable the entry of data in to the RAM.
4. Position the 'Set Address' switch in the '1' position to allow random access of memory.
5. Set the desired address (any address at random) using the address bit switches.
6. Set the desired data (refer table for the data to be entered in each location) using the data bit switches.

NOTES

7. Observe that the data is indicated by the LEDs (D4 toD1). This is because the data is written on to the RAM.
8. Also observe that the data is indicated by the data outputs is the compliment of the data input (refer truth table condition ME =L and WE=L).

Address		Data	
0h	0000	Ah	1010
1h	0001	Ch	1100
2h	0010	7h	0111
3h	0011	3h	0011
4h	0100	8h	1000
5h	0101	2h	0010
6h	0110	Bh	1011
7h	0111	Fh	1111
8h	1000	0h	0000
9h	1001	4h	0100
Ah	1010	1h	0001
Bh	1011	6h	0110
Ch	1100	5h	0101
Dh	1101	Eh	1110
Eh	1110	9h	1001
Fh	1111	Dh	1101

9. After each data entry, make a note of the location where data is entered. This is to make sure, that we are not re-entering data in the same location.
10. Repeat steps 4 and 5 until data has been entered in all the addresses listed in the above Table.
11. Position the 'Read/Write' switch in the 'Read' position, to disable data entry.
12. This completes data entry.

Read Operation

1. Position the 'Stack/Queue' switch in the 'Queue' position.
2. Position the 'Set Address' switch in the '0' position to allow random access of memory.
3. Position 'Read/Write' switches in the 'Read' position, to disable unauthorized entry of data.
4. Set the desired address (any address at random).
5. Observe that the data entered in the location is indicated by the LEDs (D4 toD1). This is because the data was written during the data entry procedure.
6. Also observe that the data indicated by the data out puts is the compliment of the data input (refer truth table condition ME=L and WE=H).

Chapter – 3: Intel 8085 Microprocessor

The 8085 is an 8-bit microprocessor, which was launched by Intel team in 1976 with the help of NMOS technology. It is a programmable electronic circuit, capable of decision making and computing similar to central processing unit of a modern

computer. It is used in various types of electronic devices like mobile phones ovens, washing machines, printers, etc. and for space applications like radars, satellites and flights.

8085 has the following configuration –

NOTES

- 8-bit Data Bus
- 16-bit Address Bus, which can Address up to 64KB
- A 16-bit Program Counter
- A 16-bit Stack Pointer
- Six 8-bit Registers Arranged in Pairs: BC, DE, HL
- Requires +5V Supply to Operate at 3.2 MHZ Single Phase Clock

Figure 1 shows the pin-out diagram of a typical 8085 microprocessor chip.

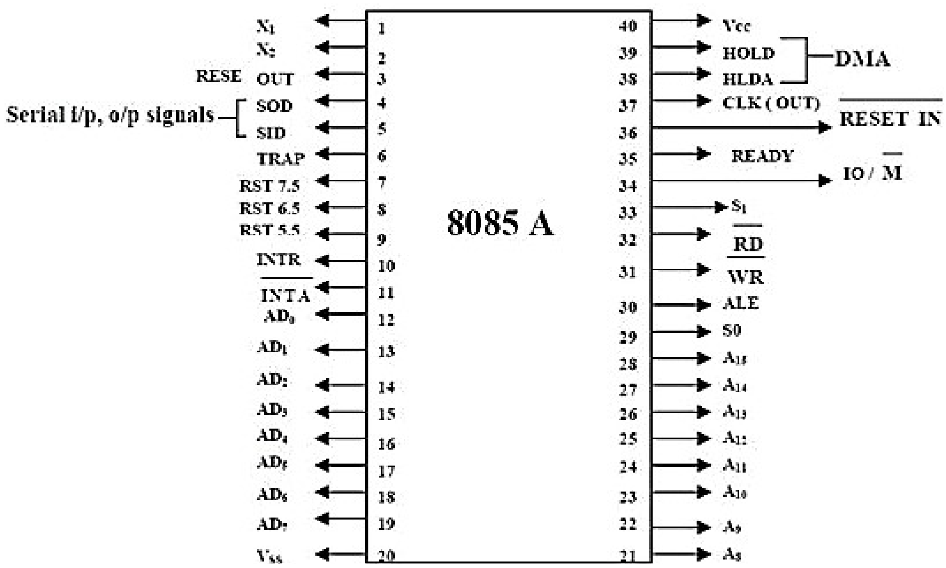


Fig. 1

8085 Microprocessor – Functional Units

8085 consists of the following functional units:

Arithmetic and Logic Unit

It is designed to perform the arithmetic and logical operations like Addition, Subtraction, AND, OR, etc., on 8-bit data. It stores the result of operations in Accumulator.

Accumulator

The accumulator is an 8 bit register included as a part of Arithmetic Logic Unit (ALU). This register is used to store 8 bit data and to perform arithmetic and logical operations.

NOTES

General Purpose Register

There are six general purpose registers in 8085 microprocessor, i.e. B, C, D, E, H and L. Each register is capable of holding 8-bit data.

These registers can work in pair as well to hold 16-bit data and their pairing combination can only work like B-C, D-E and H-L.

Program Counter

This 16 bit register deals with sequencing the execution of step by step instructions. It is used to store the memory address location of the next instruction which needs to be executed. Microprocessor increments the program counter whenever an instruction is being executed, so that the program counter points to the memory address of the next instruction which is going to be executed after the current instruction.

Stack Pointer

It is also a 16-bit register works like stack, which is always incremented/ decremented by 2 during push and pop operations.

Temporary Register

It is an 8-bit register, which holds the temporary data of arithmetic and logical operations.

Flag Register

It is an 8-bit register consisting five 1-bit flip-flops, which hold either 0 or 1 depending upon the result stored in the accumulator.

These are the following set of 5 flip-flops:

- Sign (S)
- Zero (Z)
- Auxiliary Carry (AC)
- Parity (P)
- Carry (C)

Its bit position is shown in the following table:

D7	D6	D5	D4	D3	D2	D1	D0
S	Z		AC		P		CY

Timing and Control Unit

This unit provides timing and control signal to the microprocessor to perform operations. Given below are the timing and control signals, which control external and internal circuits.

- Control Signals: READY, RD’, WR’, ALE
- Status Signals: S0, S1, IO/M’

- DMA Signals: HOLD, HLDA
- RESET Signals: RESET IN, RESET OUT

Interrupt Control

NOTES

As suggested by the name, it controls the interrupts during a process. When a microprocessor is executing a main program and if an interrupt occurs, the microprocessor shifts the control from the main program to process the incoming request. Once the request is completed, the control goes back to the main program.

There are five interrupt signals in 8085 microprocessor: INTR, RST 7.5, RST 6.5, RST 5.5, TRAP.

Serial Input/Output Control

It controls the serial data communication by using these two instructions: SID (Serial Input Data) and SOD (Serial Output Data).

Address Bus and Data Bus

Data bus is a bidirectional bus and carries the data to be stored, whereas address bus carries the location to where it should be stored and it is unidirectional. It is used to transfer the data and Address I/O devices.

8085 Architecture

Figure 2 depicts the architecture of 8085 microprocessor.

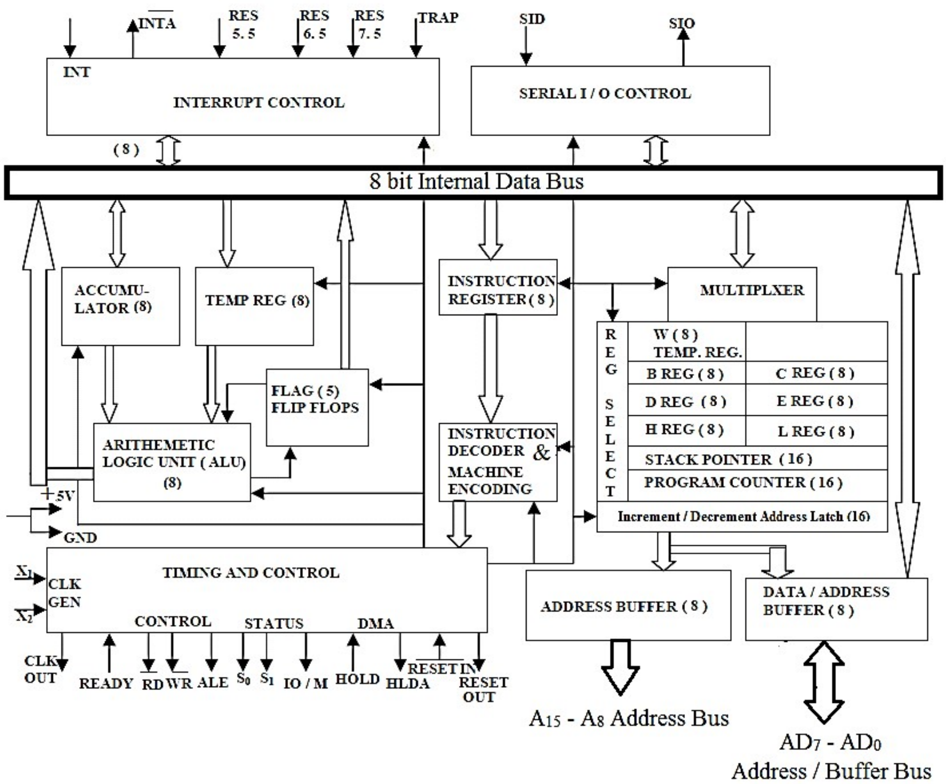


Fig. 2

NOTES

Operations of Microprocessor: The microprocessor performs the following four operations using Address Bus, Data Bus and Control Bus:

- **Memory Read:** Reads Data (or Instruction) from Memory.
- **Memory Write:** Writes Data (or Instruction) into Memory.
- **I/O Read:** Accepts Data from Input Device.
- **I/O Write:** Sends Data to Output Device.

The 8085 Instruction Format: An instruction is a command to the microprocessor to perform a given operation on a specified data. Each instruction consists of two parts, one is task to be performed, called the operation code (op code), and the second is the data to be operated on called the operand. The 8085-instruction set is classified according to size of memory it takes.

- **One-Byte Instructions:** A 1-byte instruction contains the op code and operand in the same byte.
- **Two-Byte Instructions:** In a two-byte instruction, the first byte specifies the operation code and the second byte specifies the operand. Source operand is a data byte immediately following the op code.
- **Three-Byte Instructions:** In any three-byte instruction, the first byte specifies the op code and the following two bytes specify the 16-bit address. Furthermore, the second byte is the low-order address and the third byte is the high-order address.

Important Instructions of 8085

Table below gives important instructions for 8085 which will be useful for writing assembly language programs.

Control Instructions

Opcode	Operand	Explanation of Instruction	Description
NOP	**none**	No operation	No operation is performed. The instruction is fetched and decoded. However no operation is executed. `Example: NOP`
HLT	**none**	Halt and enter wait state	The CPU finishes executing the current instruction and halts any further execution. An interrupt or reset is necessary to exit from the halt state. `Example: HLT`

Logical Instructions

NOTES

Opcode	Operand	Explanation of Instruction	Description
CMP	**R** **M**	Compare register or memory with accumulator	The contents of the operand (register or memory) are M compared with the contents of the accumulator. Both contents are preserved. The result of the comparison is shown by setting the flags of the PSW as follows: if (A) < (reg/mem): carry flag is set if (A) = (reg/mem): zero flag is set if (A) > (reg/mem): carry and zero flags are reset Example: CMP B or CMP M
CPI	**8-bit data**	Compare immediate with accumulator	The second byte (8-bit data) is compared with the contents of the accumulator. The values being compared remain unchanged. The result of the comparison is shown by setting the flags of the PSW as follows: if (A) < data: carry flag is set if (A) = data: zero flag is set if (A) > data: carry and zero flags are reset Example: CPI 89H
ANA	**R** **M**	Logical AND register or memory with accumulator	The contents of the accumulator are logically ANDed with M the contents of the operand (register or memory), and the result is placed in the accumulator. If the operand is a memory location, its address is specified by the contents of HL registers. S, Z, P are modified to reflect the result of the operation. CY is reset. AC is set. Example: ANA B or ANA M
ANI	**8-bit data**	Logical AND immediate with accumulator	The contents of the accumulator are logically ANDed with the 8-bit data (operand) and the result is placed in the accumulator. S, Z, P are modified to reflect the result of the operation. CY is reset. AC is set. Example: ANI 86H
XRA	**R** **M**	Exclusive OR register or memory with accumulator	The contents of the accumulator are Exclusive ORed with M the contents of the operand (register or memory), and the result is placed in the accumulator. If the operand is a memory location, its address is specified by the contents of HL registers. S, Z, P are modified to reflect the result of the operation. CY and AC are reset. Example: XRA B or XRA M
XRI	**8-bit data**	Exclusive OR immediate with accumulator	The contents of the accumulator are Exclusive ORed with the 8-bit data (operand) and the result is placed in the accumulator. S, Z, P are modified to reflect the result of the operation. CY and AC are reset. Example: XRI 86H
ORA	**R** **M**	Logical OR register or memory with accumulator	The contents of the accumulator are logically ORed with M the contents of the operand (register or memory), and the result is placed in the accumulator. If the operand is a memory location, its address is specified by the contents of HL registers. S, Z, P are modified to reflect the result of the operation. CY and AC are reset. Example: ORA B or ORA M
ORI	**8-bit data**	Logical OR immediate with accumulator	The contents of the accumulator are logically ORed with the 8-bit data (operand) and the result is placed in the accumulator. S, Z, P are modified to reflect the result of the operation. CY and AC are reset. Example: ORI 86H
RLC	**none**	Rotate accumulator left	Each binary bit of the accumulator is rotated left by one position. Bit D7 is placed in the position of D0 as well as in the Carry flag. CY is modified according to bit D7. S, Z, P, AC are not affected. Example: RLC
RRC	**none**	Rotate accumulator right	Each binary bit of the accumulator is rotated right by one position. Bit D0 is placed in the position of D7 as well as in the Carry flag. CY is modified according to bit D0. S, Z, P, AC are not affected. Example: RRC
RAL	**none**	Rotate accumulator left through carry	Each binary bit of the accumulator is rotated left by one position through the Carry flag. Bit D7 is placed in the Carry flag, and the Carry flag is placed in the least significant position D0. CY is modified according to bit D7. S, Z, P, AC are not affected. Example: RAL
RAR	**none**	Rotate accumulator right through carry	Each binary bit of the accumulator is rotated right by one position through the Carry flag. Bit D0 is placed in the Carry flag, and the Carry flag is placed in the most significant position D7. CY is modified according to bit D0. S, Z, P, AC are not affected. Example: RAR

NOTES

CMA	**none**	Complement accumulator	The contents of the accumulator are complemented. No flags are affected. Example: CMA
CMC	**none**	Complement carry	The Carry flag is complemented. No other flags are affected. Example: CMC
STC	**none**	Set Carry	Set Carry Example: STC

Branching Instructions

<table>
<tr><th>Opcode</th><th>Operand</th><th>Explanation of Instruction</th><th>Description</th></tr>
<tr><td>JMP</td><td>16-bit address</td><td>Jump unconditionally</td><td>The program sequence is transferred to the memory location specified by the 16-bit address given in the operand.
Example: JMP 2034H or JMP XYZ</td></tr>
<tr><td><table>
<tr><td>Opcode</td><td>Description</td><td>Flag Status</td></tr>
<tr><td>JC</td><td>Jump on Carry</td><td>CY = 1</td></tr>
<tr><td>JNC</td><td>Jump on no Carry</td><td>CY = 0</td></tr>
<tr><td>JP</td><td>Jump on positive</td><td>S = 0</td></tr>
<tr><td>JM</td><td>Jump on minus</td><td>S = 1</td></tr>
<tr><td>JZ</td><td>Jump on zero</td><td>Z = 1</td></tr>
<tr><td>JNZ</td><td>Jump on no zero</td><td>Z = 0</td></tr>
<tr><td>JPE</td><td>Jump on parity even</td><td>P = 1</td></tr>
<tr><td>JPO</td><td>Jump on parity odd</td><td>P = 0</td></tr>
</table></td><td>16-bit address</td><td>Jump conditionally</td><td>The program sequence is transferred to the memory location specified by the 16-bit address given in the operand based on the specified flag of the PSW as described below.
Example: JZ 2034H or JZ XYZ</td></tr>
<tr><td><table>
<tr><td>Opcode</td><td>Description</td><td>Flag Status</td></tr>
<tr><td>CC</td><td>Call on Carry</td><td>CY = 1</td></tr>
<tr><td>CNC</td><td>Call on no Carry</td><td>CY = 0</td></tr>
<tr><td>CP</td><td>Call on positive</td><td>S = 0</td></tr>
<tr><td>CM</td><td>Call on minus</td><td>S = 1</td></tr>
<tr><td>CZ</td><td>Call on zero</td><td>Z = 1</td></tr>
<tr><td>CNZ</td><td>Call on no zero</td><td>Z = 0</td></tr>
<tr><td>CPE</td><td>Call on parity even</td><td>P = 1</td></tr>
<tr><td>CPO</td><td>Call on parity odd</td><td>P = 0</td></tr>
</table></td><td>16-bit address</td><td>Unconditional subroutine call</td><td>The program sequence is transferred to the memory location specified by the 16-bit address given in the operand. Before the transfer, the address of the next instruction after CALL (the contents of the program counter) is pushed onto the stack.
Example: CALL 2034H or CALL XYZ</td></tr>
<tr><td>RET</td><td>none</td><td>Return from subroutine unconditionally</td><td>The program sequence is transferred from the subroutine to the calling program. The two bytes from the top of the stack are copied into the program counter,and program execution begins at the new address.
Example: RET</td></tr>
</table>

Arithmetic Instructions

Opcode	Operand	Explanation of Instruction	Description
ADD	R M	Add register or memory, to accumulator	The contents of the operand (register or memory) are added to the contents of the accumulator and the result is stored in the accumulator. If the operand is a memory location, its location is specified by the contents of the HL registers. All flags are modified to reflect the result of the addition. Example: ADD B or ADD M
ADC	R M	Add register to accumulator with carry	The contents of the operand (register or memory) and M the Carry flag are added to the contents of the accumulator and the result is stored in the accumulator. If the operand is a memory location, its location is specified by the contents of the HL registers. All flags are modified to reflect the result of the addition. Example: ADC B or ADC M
ADI	8-bit data	Add immediate to accumulator	The 8-bit data (operand) is added to the contents of the accumulator and the result is stored in the accumulator. All flags are modified to reflect the result of the addition. Example: ADI 45H
ACI	8-bit data	Add immediate to accumulator with carry	The 8-bit data (operand) and the Carry flag are added to the contents of the accumulator and the result is stored in the accumulator. All flags are modified to reflect the result of the addition. Example: ACI 45H
LXI	Reg. pair, 16-bit data	Load register pair immediate	The instruction loads 16-bit data in the register pair designated in the operand. Example: LXI H, 2034H or LXI H, XYZ
DAD	Reg. pair	Add register pair to H and L registers	The 16-bit contents of the specified register pair are added to the contents of the HL register and the sum is stored in the HL register. The contents of the source register pair are not altered. If the result is larger than 16 bits, the CY flag is set. No other flags are affected. Example: DAD H
SUB	R M	Subtract register or memory from accumulator	The contents of the operand (register or memory) are subtracted from the contents of the accumulator, and the result is stored in the accumulator. If the operand is a memory location, its location is specified by the contents of the HL registers. All flags are modified to reflect the result of the subtraction. Example: SUB B or SUB M
SBB	R M	Subtract source and borrow from accumulator	The contents of the operand (register or memory) and M the Borrow flag are subtracted from the contents of the accumulator and the result is placed in the accumulator. If the operand is a memory location, its location is specified by the contents of the HL registers. All flags are modified to reflect the result of the subtraction. Example: SBB B or SBB M
SUI	8-bit data	Subtract immediate from accumulator	The 8-bit data (operand) is subtracted from the contents of the accumulator and the result is stored in the accumulator. All flags are modified to reflect the result of the subtraction. Example: SUI 45H
SBI	8-bit data	Subtract immediate from accumulator with borrow	The contents of register H are exchanged with the contents of register D, and the contents of register L are exchanged with the contents of register E. Example: XCHG
INR	R M	Increment register or memory by 1	The contents of the designated register or memory) are incremented by 1 and the result is stored in the same place. If the operand is a memory location, its location is specified by the contents of the HL registers. Example: INR B or INR M
INX	R	Increment register pair by 1	The contents of the designated register pair are incremented by 1 and the result is stored in the same place. Example: INX H
DCR	R M	Decrement register or memory by 1	The contents of the designated register or memory are M decremented by 1 and the result is stored in the same place. If the operand is a memory location, its location is specified by the contents of the HL registers. Example: DCR B or DCR M
DCX	R	Decrement register pair by 1	The contents of the designated register pair are decremented by 1 and the result is stored in the same place. Example: DCX H
DAA	none	Decimal adjust accumulator	The contents of the accumulator are changed from a binary value to two 4-bit binary coded decimal (BCD) digits. This is the only instruction that uses the auxiliary flag to perform the binary to BCD conversion, and the conversion procedure is described below. S, Z, AC, P, CY flags are altered to reflect the results of the operation. If the value of the low-order 4-bits in the accumulator is greater than 9 or if AC flag is set, the instruction adds 6 to the low-order four bits. If the value of the high-order 4-bits in the accumulator is greater than 9 or if the Carry flag is set, the instruction adds 6 to the high-order four bits. Example: DAA

NOTES

Dsata Transfer Instructions

NOTES

Opcode	Operand	Explanation of Instruction	Description
MOV	**Rd, Rs** **M, Rs** **Rd, M**	Copy from source(₹) to destination(Rd)	This instruction copies the contents of the source register into the destination register; the contents of the source register are not altered. If one of the operands is a memory location, its location is specified by the contents of the HL registers. Example: MOV B, C or MOV B, M
MVI	**Rd, data** **M, data**	Move immediate 8-bit	The 8-bit data is stored in the destination register or memory. If the operand is a memory location, its location is specified by the contents of the HL registers. Example: MVI B, 57H or MVI M, 57H
LDA	**16-bit address**	Load accumulator	The contents of a memory location, specified by a 16-bit address in the operand, are copied to the accumulator. The contents of the source are not altered. Example: LDA 2034H
LDAX	**B/D Reg. pair**	Load accumulator indirect	The contents of the designated register pair point to a memory location. This instruction copies the contents of that memory location into the accumulator. The contents of either the register pair or the memory location are not altered. Example: LDAX B
LXI	**Reg. pair, 16-bit data**	Load register pair immediate	The instruction loads 16-bit data in the register pair designated in the operand. Example: LXI H, 2034H or LXI H, XYZ
LHLD	**16-bit address**	Load H and L registers direct	The instruction copies the contents of the memory location pointed out by the 16-bit address into register L and copies the contents of the next memory location into register H. The contents of source memory locations are not altered. Example: LHLD 2040H
STA	**16-bit address**	16-bit address	The contents of the accumulator are copied into the memory location specified by the operand. This is a 3-byte instruction, the second byte specifies the low-order address and the third byte specifies the high-order address. Example: STA 4350H
STAX	**Reg. pair**	Store accumulator indirect	The contents of the accumulator are copied into the memory location specified by the contents of the operand (register pair). The contents of the accumulator are not altered. Example: STAX B
SHLD	**16-bit address**	Store H and L registers direct	The contents of register L are stored into the memory location specified by the 16-bit address in the operand and the contents of H register are stored into the next memory location by incrementing the operand. The contents of registers HL are not altered. This is a 3-byte instruction, the second byte specifies the low-order address and the third byte specifies the high-order address. Example: SHLD 2470H
XCHG	**none**	Exchange H and L with D and E	The contents of register H are exchanged with the contents of register D, and the contents of register L are exchanged with the contents of register E. Example: XCHG
SPHL	**none**	Copy H and L registers to the stack pointer	The instruction loads the contents of the H and L registers into the stack pointer register, the contents of the H register provide the high-order address and the contents of the L register provide the low-order address. The contents of the H and L registers are not altered. Example: SPHL
XTHL	**none**	Exchange H and L with top of stack	The contents of the L register are exchanged with the stack location pointed out by the contents of the stack pointer register. The contents of the H register are exchanged with the next stack location (SP+1); however, the contents of the stack pointer register are not altered. Example: XTHL
PUSH	**Reg. pair**	Push register pair onto stack	The contents of the register pair designated in the operand are copied onto the stack in the following sequence. The stack pointer register is decremented and the contents of the highorder register (B, D, H, A) are copied into that location. The stack pointer register is decremented again and the contents of the low-order register (C, E, L, flags) are copied to that location. Example: PUSH B or PUSH A
POP	**Reg. pair**	Pop off stack to register pair	The contents of the memory location pointed out by the stack pointer register are copied to the low-order register (C, E, L, status flags) of the operand. The stack pointer is incremented by 1 and the contents of that memory location are

			copied to the high-order register (B, D, H, A) of the operand. The stack pointer register is again incremented by 1. Example: POP H or POP A
OUT	8-bit port address	Output data from accumulator to a port with 8-bit address	The contents of the accumulator are copied into the I/O port specified by the operand. Example: OUT F8H
IN	8-bit port address	Input data to accumulator from a port with 8-bit address	The contents of the input port designated in the operand are read and loaded into the accumulator. Example: IN 8CH

NOTES

EXPERIMENT 4: Write an Assembly Language Programming for Addition of Two 8-Bit Unsigned Numbers

Objective

To performing simple arithmetic operations of addition using 8085 Microprocessor and handling the 8085-microprocessor kit.

Apparatus: Experiment Kit, SMPS.

Program

Address	Instruction
7000	LDA 7100H
7003	MOV B,A
7004	LDA 7101H
7007	ADD B
7008	STA 7102H
700B	HLT

Procedure

- Draw flow chart for the logic.
- Prepare an assembly language program with starting address 7000H.
- Check the 'Op Code' for the instructions used in the program.
- Connect the SMPS to Microprocessor kit.
- Write the program and assign two different data.
- Check the answer using Microprocessor kit.

Experiment 5

EXPERIMENT 5: Write an Assembly Language Programming for Subtraction of Two 8-Bit Unsigned Numbers

Objective

To perform simple arithmetic operations of subtraction using 8085 Microprocessor.

(i) Minuend is Bigger than Subtrahend

(ii) Result with Provision of Sign Indication

NOTES

Apparatus: Experiment Kit, SMPS.

Program for (i)

Address	Instruction
7000	LDA 7100H
7003	MOV B,A
7004	LDA 7101H
7007	SUB B
7008	STA 7003H
700B	HLT

Program for (ii)

Address	Instruction
7000	MVI C,00H
7002	LXI D, (Minuend, Subtrahend)H
7005	LXI H,(Subtrahend,Minuend)H
7008	MOV A, L
7009	CMP H
700A	JNC ##
700D	XCHG
700E	INR C
700F	## MOV A, L
7010	SUB H
7011	STA 7100H
7014	MOV A, C
7015	STA 7101H
7018	HLT

Procedure

- Draw flow chart for the logic.
- Prepare an assembly language program with starting address 7000H.
- Check the 'Op Code' for the instructions used in the program.
- Connect the SMPS to Microprocessor kit.
- Write the program and assign two different data.
- Check the answer using Microprocessor kit

Experiment No. 6

EXPERIMENT 6: Write an Assembly Language Programming for Addition of Two 16-Bit Numbers and Draw the Corresponding Flow Chart as well.

NOTES

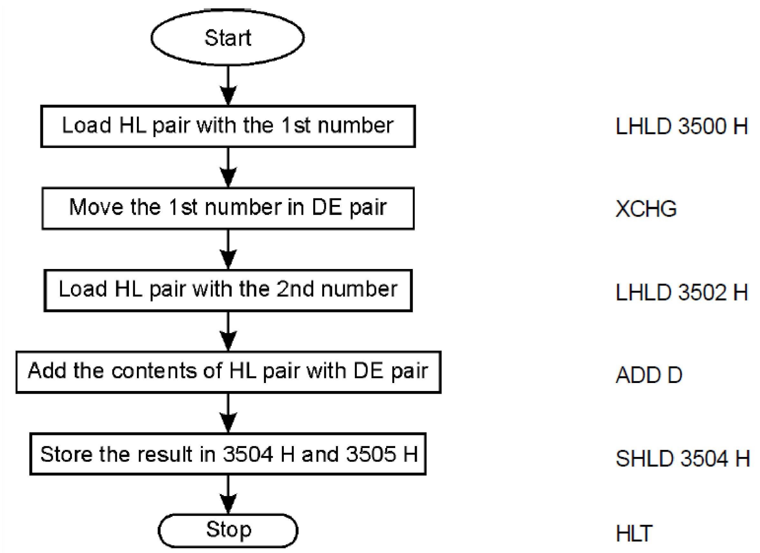
Objective

To perform complex arithmetic operations of 16-bit addition using 8085 Microprocessor.

Apparatus: Experiment Kit, SMPS.

Program and Flowchart

Let the two sixteen- bit numbers are stored at memory locations 3500 H to 3503 H. The result of addition is to be stored at memory locations 3504 H and 3505 H. The flowchart and the program will look like as follow.



Procedure

- Draw flow chart for the logic.
- Prepare an assembly language program.
- Check the 'Op Code' for the instructions used in the program.
- Connect the SMPS to Microprocessor kit.
- Check the answer using Microprocessor kit.

Experiment No. 7

EXPERIMENT 7: Write a Program to Compare Two Numbers and Store the Greater Value in a Different Memory Location.

Objective

Performing logical operations using 8085 Microprocessor.

Apparatus: Experiment Kit, SMPS.

Program

NOTES

The program compares two numbers stored in the 5729H and 5749H memory location respectively and whichever number is present in the accumulator in the end is the larger of the two numbers.

Address	**Instruction**
7000	LDA 5729H
7003	MOV B,A
7005	LDA 5739H
7008	CMP B
7009	JNC JUMP
700C	MOV A,B
700E	JUMP:STA 5749H
7011	HLT

Procedure

- Draw flow chart for the logic.
- Prepare an assembly language program.
- Check the 'Op Code' for the instructions used in the program.
- Connect the SMPS to Microprocessor kit.
- And confirm the results.

Experiment No. 8

EXPERIMENT 8: Write an Assembly Language Program in 8085 Microprocessor to Sort a given list of n Numbers.

Objective

Performing logical operations using 8085 Microprocessor.

Apparatus: Experiment Kit, SMPS.

Program

Size of list is stored at 2040H and list of numbers from 2041H onwards.

Algorithm

1. Load size of list in C register and set D register to be 0.
2. Decrement C as for n elements n-1 comparisons occur.
3. Load the starting element of the list in Accumulator.
4. Compare Accumulator and next element.
5. If accumulator is less than next element jump to Step 8.
6. Swap the two elements.

7. Set D register to 1.
8. Decrement C.
9. If C>0 take next element in Accumulator and go to Step 4.
10. If D=0, this means in the iteration, no exchange takes place consequently we know that it will not take place in further iterations so the loop in exited and program is stopped.
11. Jump to Step 1 for further iterations.

NOTES

ADDRESS	LABEL	INSTRUCTION	COMMENT
2000H	START	LXI H, 2040H	Load size of array
2003H		MVI D, 00H	Clear D register to set up a flag
2005H		MOV C, M	Set C register with number of elements in list
2006H		DCR C	Decrement C
2007H		INX H	Increment memory to access list
2008H	CHECK	MOV A, M	Retrieve list element in Accumulator
2009H		INX H	Increment memory to access next element
200AH		CMP M	Compare Accumulator with next element
200BH		JC NEXTBYTE	If accumulator is less then jump to NEXTBYTE
200EH		MOV B, M	Swap the two elements
200FH		MOV M, A	
2010H		DCX H	
2011H		MOV M, B	
2012H		INX H	
2013H		MVI D, 01H	If exchange occurs save 01 in D register
2015H	NEXTBYTE	DCR C	Decrement C for next iteration
2016H		JNZ CHECK	Jump to CHECK if C>0
2019H		MOV A, D	Transfer contents of D to Accumulator
201AH		CPI 01H	Compare accumulator contents with 01H
201CH		JZ START	Jump to START if D=01H
201FH		HLT	HALT

Procedure

- Draw flow chart for the logic.
- Prepare an assembly language program.
- Check the ‘Opcode’ for the instructions used in the program.
- Connect the SMPS to Microprocessor kit.
- Verify the results.

NOTES

Experiment No. – 9

EXPERIMENT 9: Write an Assembly Language Program in 8085 Microprocessor to Convert an 8-Bit BCD Number into Hexadecimal Number.

Objective

To convert BCD numbers in memory to equivalent HEX number using 8085 instruction set.

Apparatus: Experiment Kit, SMPS.

Program

Assume that starting address of the program is 2000, input memory locations, 2050, 2051, and output memory location is 2052.

Algorithm

1. Initialize memory pointer to 2050 H
2. Get the most significant digit
3. Multiply the MSD by 10 using repeated addition
4. Add LSD to result obtained in above Step
5. Store the converted result in memory 2052

MEMORY ADDRESS	MNEMONICS
2000	LXI H, 2050
2003	MOV A, M
2004	ADD A
2005	MOV B, A
2006	ADD A
2007	ADD A
2008	ADD B
2009	INX H
200A	ADD M
200B	INX H
200C	MOV M, A
200D	HLT

Procedure

- Draw flow chart for the logic.
- Prepare an assembly language program.
- Check the 'Op Code' for the instructions used in the program.
- Connect the SMPS to Microprocessor kit.
- And confirm the results.

NOTES

EXPERIMENT 10: Planck's Constant

Introduction – If the photons of frequency higher than a minimum threshold are incident on metal, then the electrons are emitted from its surface. This is known as the Photoelectric Effect and the electrons are known as photoelectrons. The kinetic energy of the photoelectrons, thus, depend upon the energy of the incident radiation. This relation helps to determine the value of Planck's constant.

Theory – Planck introduced the concept of photon defined the energy of a photon to be *hv,* where *h* is the Planck's constant and *v* is the frequency of the electromagnetic radiation. When a suitable light illuminates the surface of a metal, then the energy absorbed by the electron will cause an electron to move out of the metal surface. The minimum energy required to take this out of the metal surface is known as work function (ϕ). The remaining energy imparts the kinetic energy ($\frac{1}{2}mv^2$) to the electron. Therefore, Einstein's equation on the photoelectric effect can be written as –

$$hv = \phi + \frac{1}{2}mv^2 \quad ...(1)$$

$$hv = hv_o + \frac{1}{2}mv^2 \quad ...(2)$$

The following information can be interpreted from the Einstein's photoelectric equation discussed above-

1. The frequency v_0 is called the threshold frequency, which is the minimum frequency required for escaping the electron from the metal surface. The photoelectric effect at a frequency lower than this is not possible.
2. The number of electrons emitted from the metal surface is directly proportional to the number of incident photons (intensity).
3. The kinetic energy of an individual photoelectron is directly proportional to the frequency of the incident photon.

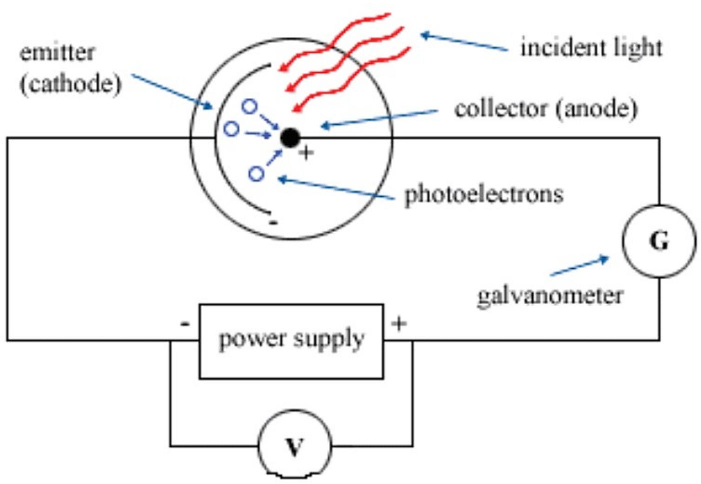


Fig. 1 *Photoelectric Effect*

NOTES

In this experiment, the incident light strikes on the cathode, and the electrons are emitted through its surface. Light filters are placed in front of the photoelectric tube which will allow only a particular frequency to reach the cathode. The electrons emitted from the cathode move towards anode and create a current. Therefore a negative potential is applied on the anode to repel the incoming electrons. When the repulsive force is strong enough to block the incoming electrons then and the current running in the circuit stops. This energy is known as stopping potential. This can be represented as eV where 'e' is the charge on the electron and V is the negative potential applied at the anode. The stopping potential is directly proportional to the kinetic energy of the electrons. It inference that higher negative potential is required to stop the electrons carrying high kinetic energy. The Equation (1) can be written as,

$$hv = \phi + eV \quad ...(3)$$

If two frequencies v_1 and v_2 are incident on the cathode individually and V_1 and V_2 are the respective stopping potentials then Equation (3) can be mentioned as,

$$hv = \phi + eV_1 \quad ...(4)$$

$$hv_2 = \phi + eV_2 \quad ...(5)$$

Subtracting Equation 4 from Equation 5, we get

$$h\,(v_2 - v_1) = e\,(V_2 - V_1) \quad ...(6)$$

We know that,

$$v = c/\lambda \quad ...(7)$$

Where c is the velocity of light and λ is the wavelength. Inserting Equation 7 in Equation 6. We get,

$$hc\frac{\lambda_1 - \lambda_2}{\lambda_1\lambda_2} = e(V_2 - V_1) \quad ...(8)$$

$$h = \frac{e(V_2 - V_1)\lambda_1\lambda_2}{c(\lambda_1 - \lambda_2)} \quad ...(9)$$

The value of Planck's constant can be determined using this formula providing the stopping potential for different incident wavelengths.

Aim – To determine the Value of Planck's Constant using Photocell Apparatus.

Apparatus – Optical Bench, Mercury Vapor Lamp Fitted in a Box, DC Power Supply, Photocell with Mount Adjustments and Housing, Optical Filters (e.g., Blue (490 nm), Green (540 nm), Red (580 nm), etc.)

Procedure

1. Place the mercury lamp and the photocell in a line on the optical bench.
2. Switch 'ON' the nanometer and adjust the zero on nanometer when the mercury lamp is 'OFF'.

NOTES

3. Place the filter between the photocell and the light source and then switch 'ON' the light source.
4. Adjust the slit so that you observe some deflection in the photocurrent meter when the anode potential is kept at 'Zero'.
5. Note the photon current for zero anode potential and start filling its values in Table 1.
6. Now, increase the negative potential of the anode and measure the corresponding photocurrent.
7. Keep increasing the negative potential and note down the corresponding photocurrent till it becomes zero.
8. Now, repeat the experiment with other available light filters.
9. Plot the curve between negative anode potential on the x-axis and the corresponding photocurrent along the y-axis for different wavelengths corresponding to different filters.
10. Find the stopping potential for each wavelength from the graph and calculate the value of Planck's constant for each pair of observations. Find the mean for better accuracy.

Table 1

Sr. No.	Negative Anode Potential (mV)	Photo-Current (nA)		
		Blue-Filter 490 nm	Green-Filter 540 nm	Red-Filter 580 nm
1.				
2.				
3.				
4.				
5.				
6.				
7.				
8.				
9.				
10.				
--				
--				

Formula Used

Stopping Potential for Red Filter (V_1) = ……………………. V

Stopping Potential for Green Filter (V_2) = ………………….. V

Stopping Potential for Blue Filter (V_3) = …………………... V

Find Planck's Constant using Equation 9.

$$h_{12} = \frac{e(V_2 - V_1)\lambda_1\lambda_2}{c(\lambda_1 - \lambda_2)}$$

$$h_{23} = \frac{e(V_2 - V_1)\lambda_1\lambda_2}{c(\lambda_1 - \lambda_2)}$$

NOTES

$$h_{13} = \frac{e(V_2 - V_1)\lambda_1\lambda_2}{c(\lambda_1 - \lambda_2)}$$

$$Mean\ h = \frac{h_{12} + h_{23} + h_{13}}{3} = \cdots \ldots \ldots \ldots \ldots \ldots . Js$$

Maximum Percentage Error

$$\%\ error = \frac{Observed\ Value - Standard\ Value}{Standard\ Value} \times 100$$

Standard Value (*h*) = 6.6262×10^{-34}

Precautions and Source of Errors

1. The reading should be taken in small steps.
2. The surface of the anode material should be cleaned and illuminated properly.
3. The stopping potential should be measured from the graph to reduce the experimental errors.
4. The experiment should be done for at least 3 wavelengths.

The photocell source of light and the filter should be linearly aligned.

EXPERIMENT 11: E/m using Thomson Method

Introduction

J. J. Thomson discovered cathode rays in his famous cathode ray experiment. The determination of the quantity of negative charge on the particles emitted in the cathode ray experiment was not that easy. Therefore, to find the properties of cathode ray particles an experiment was constructed and the charge to mass ratio of an electron was calculated.

Theory

If an electron is left inside an electric field then it experiences a force (F = eE) on it which is proportional to the electric charge on the electron (1.6×10^{-19} Coulomb) and the electric field, E, experienced by the electron. Similar to this, in a Cathode Ray Tube (CRT), the electrons pass through the electrically charged parallel plates and the electrons deflect opposite to the direction of the electric field.

$$F_E = eE \qquad ...(1)$$

Electrons deflect, under the influence of the electric field and hit the screen at spot M_1. However, the direction of the deflection of electrons can be switched

by switching the applied electric field. (Figure 1). The electric field can be explained in terms of potential as,

$$E = \frac{V}{d} \quad ...(2)$$

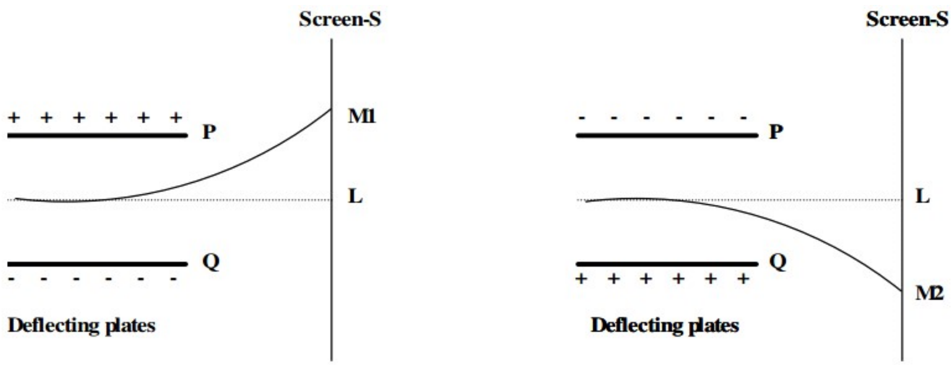


Fig. 1

Now, a magnetic field is applied perpendicular to the direction of the motion of the electrons. A similar deflection can be obtained in the reverse direction. The force on the moving charge because of the magnetic field of strength B is,

$$F_B = Bev = \frac{mv^2}{r}$$

$$\frac{e}{m} = \frac{v}{Br} \quad ...(3)$$

In equilibrium, the electric and magnetic forces balance each other and it gives,

$$eE = Bev$$

$$v = \frac{E}{B} \quad ...(4)$$

By inserting the value of Equation 4 into Equation 3 we get,

$$\frac{e}{m} = \frac{E}{B^2 r} \quad ...(5)$$

Now, here is the task to determine the radius of the path covered by the electron beam and correlate it with the spot on the CRT screen. After some geometric calculations on the structure of the CRT picture tube, it was determined that the radius of the path covered by the electron beam depends upon the length (l) of the electrically charged plates. Besides, the length (L) from the center of the plates to the screen and the vertical shift (y) of the bright spot on the screen of CRT tube when the magnetic field is applied.

NOTES

$$r = \frac{Ll}{y} \quad ...(6)$$

Thereafter, the charge to mass ratio of the cathode rays can be written as,

$$\frac{e}{m} = \frac{yE}{LlB^2} \quad ...(7)$$

The electric field E can be described as E = V/d, where V is the applied voltage on the vertical plane which is separated by a distance, d. Now, the formula becomes,

$$\frac{e}{m} = \frac{yV}{LldB^2} \quad ...(8)$$

The magnetic field between the center of the electrically charged plates cannot be measured using a gauss meter as the magnetic field produced by the bar magnets is quite small. Therefore, the magnetic field strength was calculated using a magnetometer. In this method, bar magnets are placed perpendicular to the horizontal component of earth's magnetic field (B_H) (Refer Figure 2). The CRT is aligned parallel to the magnetic meridian.

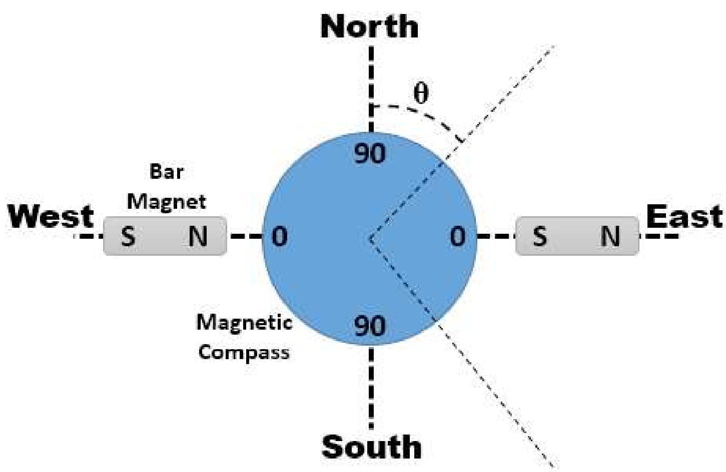


Fig. 2

To measure the magnetic field, place the magnetometer at the place of the CRT tube. Its magnets are aligned in the North-south direction. Now, place the bar magnets at the places where they were placed during the last observation and note down the deflection. The magnetic field strength at the center of the compass due to a bar magnet is given by,

$$B = B_H \tan\theta \quad ...(9)$$

Hence,

$$\frac{e}{m} = \frac{yV}{Lld(B_H\,tan\theta)^2} \qquad ...(10)$$

NOTES

Where,

y – Deflection of the Spot along y-Axis on CRT Screen

L – Length from the Center of the Plates to the Screen

l – Length of Electrically Charged Plates

d – Distance between the Electrically Charged Plates

V – Deflection Voltage

– Horizontal Component of Earth's Magnetic Field

Aim – Determination of E/m of an Electron by Thomson's Method.

Apparatus – Cathode Ray Tube with Power Supply, a Wooden Arrangement with Scale Bars Perpendicular to the CRT Tube, a Pair of Bar Magnets, and a Magnetometer.

Procedure

1. Mark the North-South direction on the wooden table using a magnetometer.
2. Place the wooden structure with the scaled arms perpendicular to the magnetic North-South line.
3. The wooden structure also contains the space in between the bars to place CRT. Now, place the CRT in between the arms of the wooden stand. Such that the axis of the CRT is parallel to the Earth's magnetic field.
4. The CRT is now connected to the power supply and the position, size, and brightness of the bright spot are calibrated to 0 position and minimum spot size and good brightness.
5. Apply the deflecting voltage on the electric plates of the CRT tube and note down the deflection y on the screen caused by the deflection voltage V.
6. Place two bar magnets on either side with opposite poles and at equal distance from the tube on the two arms of the wooden structure. The spot moves up or down (Y-direction) depending on how the bar magnets are placed. Place them in such a way, such that the bright spot on the CRT screen reaches back to the zero of the screen. Also, note down the distance D of the magnets from the center of the wooden structure (Refer Table 1).
7. Change the deflecting voltage and repeat the same experiment to relocate the bright spot at the center of the screen.
8. In the second part of the experiment, the polarity of the electric field is reversed so that the deflection of the spot is on the opposite side. The

NOTES

direction of the magnetic field also needs to be reversed to bring the bright spot back to the origin.

9. The CRT is now removed without disturbing the arms and a compass is placed in its place such that its center comes in between the bar magnets. And set it the way such that the 0-0 line is perpendicular to the magnetic line (Refer Figure 2). Place the magnets at the same distance and orientation and note down the deflection of the magnet.
10. Note down the other CRT related parameters for calculations.

Table 1

Sr. No.	Deflecting Voltage (V)	Spot Deflection y (cm)	Vy	Position of the Magnet D (cm)	Deflection θ	$Tan^2θ$
1.						
2.						
3.						
4.						
5.						
--						
--						

L – Length from the Center of the Plates to the Screen = ……..…m

l – Length of Electrically Charged Plates = …......................……m

d – Distance between the Electrically Charged Plates = ……....…m

– Horizontal Component of Earth's Magnetic Field = …......……m

Precautions and Source of Errors

1. Calibrate the light spot on the CRT tube carefully.
2. Do not disturb the wooden structure while removing the CRT tube or placing the magnetic compass.
3. Place the power supply of the CRT tube away from it just to avoid the interference caused by its electric field.
4. Note down the angle of deflection quite carefully only when the magnetic needle stabilizes.

EXPERIMENT 12: Millikan's Oil-Drop Experiment

Introduction

At the beginning of the 20th century, scientists discovered the existence of an electron in an atom. At that time, it was experimentally impossible to calculate the individual charge of a single electron. At that time Millikan used the concept of balancing the terminal velocity with the electrostatic force and found the charge on an electron through his famous oil-drop experiment.

Theory

NOTES

Its apparatus consists of an oil spray to spray tiny droplets. These droplets can be viewed with the help of a short focal distance telescope. The X-rays illuminate the bottom chamber causing the air to ionize (Refer Figure 1). As the droplets pass through the air, the electrons accumulate over the droplets. In some experiments, the oil drops get charged because of the frictional interaction between the nozzle and the oil. After that, there are two metal plates at the top and bottom of this chamber which is electrically charged and therefore its speed can be controlled by altering the applied voltage. Moreover, these drops can be suspended in air, by adjusting the applied voltage. Millikan observed one drop after another, varying the voltage and noting the effect. After various repetitions, he concluded that the charge on these drops is an integral multiple of a fixed number. He calculated it to be 1.5924 ×10"19 C, within one percent of the currently accepted value of 1.6022 ×10"19 C. Besides, he proposed that this was the charge of a single electron.

Low Focal Length Telescope

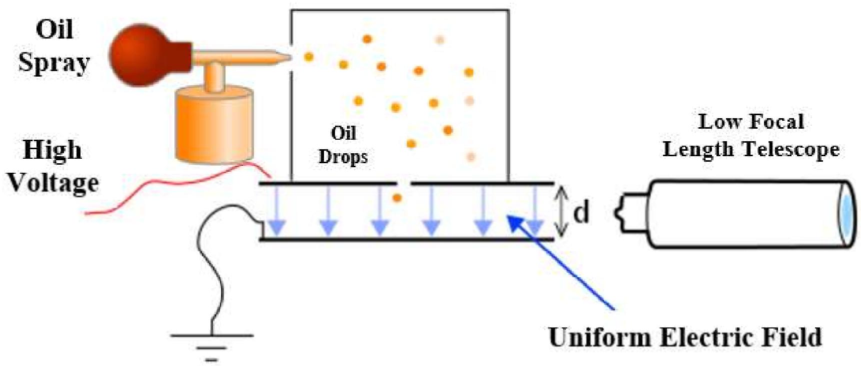


Fig. 1

In this experiment, the oil drops are allowed to fall freely between the metal plates in the absence of an electric field. The drops accelerate because of the gravitational pull but to achieve a constant velocity called the terminal velocity because of the air friction. The terminal velocity is termed as *v*. The drag force on the drop calculated from Stokes' law and is given as,

$$F_d = 6\pi\eta r v \quad ...(1)$$

Here η is the coefficient of viscosity of air and *r* is the radius of the oil drop. The apparent weight (true weight minus up thrust) for a spherical body is given by,

$$F_G = \frac{4}{3}\pi r^3 g(\rho_{oil} - \rho_{air}) \quad ...(2)$$

At terminal velocity, the oil drop attains a uniform velocity, so the total force acting on it must be zero. Therefore,

$$F_d = F_G \quad ...(3)$$

On putting Equation 1 and Equation 2 in this condition, we get

$$r^2 = \frac{9\eta v}{2g(\rho_{oil} - \rho_{air})} \quad ...(4)$$

NOTES

Now, the electric plates are electrical charges by applying a constant voltage. The electric force F_e balances the gravitational force F_G and the drop suspends in the air. Then,

$$F_e = F_G$$

$$qE = \frac{4}{3}\pi r^3 g(\rho_{oil} - \rho_{air})$$

$$q = \frac{d}{V}\frac{4}{3}\pi r^3 g(\rho_{oil} - \rho_{air}) \quad ...(5)$$

Where V is the balancing potential and d is the distance between the metal plates.

Millikan repeated this experiment a no. of times, with different strengths of the X-rays ionizing radiation. As a result, no. of electrons attaching to the oil drop varied. However, the value of the total charge was found to be a multiple of 1.6 x 10^{-19}C.

Aim – To find the charge on an oil drop using Milliken's oil drop experiment.

Apparatus – Millikan's Oil Drop Apparatus, Oil, DC Power Supply, Stopwatch.

Procedure

1. Switch on the Millikan oil drop setup with x-ray source.
2. Spray the oil and start watching the oil drops falling using a telescope.
3. Switch on the voltage supply to the metal plates, and watch the charged drops move up and down as you vary the potential difference. Choose a bright, easy-to-see oil drop, and use the voltage control to move it near the top of the screen. Hold it thereby fine-tuning the voltage. Take the reading of this voltage.
4. Switch off the voltage suddenly, and start the stopwatch simultaneously.
5. Notice a drop to travel a distance l in time t. Besides, find out its velocity *v*.
6. Use Equation 4 to find out the radius of this drop and insert its value in Equation 5 to calculate the charge q on the oil drop.

Table 1

Balancing Potential (V)	Time Taken t (s)	Distance Travelled l (m)	The Velocity of the Drop (v)	Charge on the Drop (q)	No. of Electrons (q/e)

NOTES

Air Viscosity (η) =$1.83 \pm 0.04 \times 10^{-5}$ Nsm^{-2}

Air Density (ρ_{air}) = 1.30 ± 0.05 $kg\ m^{-3}$ at 20°C

Oil Density (ρ_{oil}) = $kg\ m^{-3}$ at 20°C

Plate Spacing (d) = ………………m

$$r^2 = \frac{9\eta v}{2g(\rho_{oil} - \rho_{air})}$$

$$q = \frac{d}{V}\frac{4}{3}\pi r^3 g(\rho_{oil} - \rho_{air})$$

Precautions and Source of Errors

1. Fine-tune the stopping potential to balance the oil drop.
2. Focus the drop carefully to get its clear image and the path length.
3. Start observing the fall of the drop after some time of removing stopping as v is the terminal velocity of the drop, which takes some time to achieve.
4. Try to observe the maximum length of the path traveled by the drop to minimize the uncertainties in length and time of travel.

EXPERIMENT 13: Thermal Conductivity of a Bad Conductor

Introduction

Similar to the charge conduction phenomenon, heat also conducts through a material. The thermal conductivity is the property of a material independent of its dimensions. Alike current conduction, there are some good or some bad conductors of heat. Some materials, like copper, aluminum, and iron are good conductors of heat whereas materials like wood, glass, etc., are bad conductors. The conductivity of a bad conductor can be measured by Lee's and Charlton methods.

Theory

Thermal Conductivity of a material is the rate of heat conduction through a material of unit thickness and unit cross-section area for each Kelvin of temperature difference (Refer Figure 1).

$$\textit{Thermal Conductivity} = \frac{\textit{Heat}\ (Q) \times \textit{Length}\ (l)}{\textit{Area}\ (A) * \textit{Temperature Difference}(\Delta T)}$$

NOTES

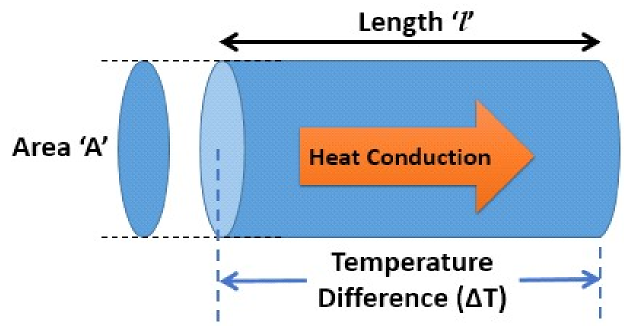


Fig. 1

The principle of this experiment is that at a steady-state, there will be constant temperature difference across the bad conductor and the rate of heat flow is constant. In the determination of the thermal conductivity of the bad conductor, the rate of flow of heat through the bad conductor is equated to the rate of loss of heat through the lower metal disc by heat radiation.

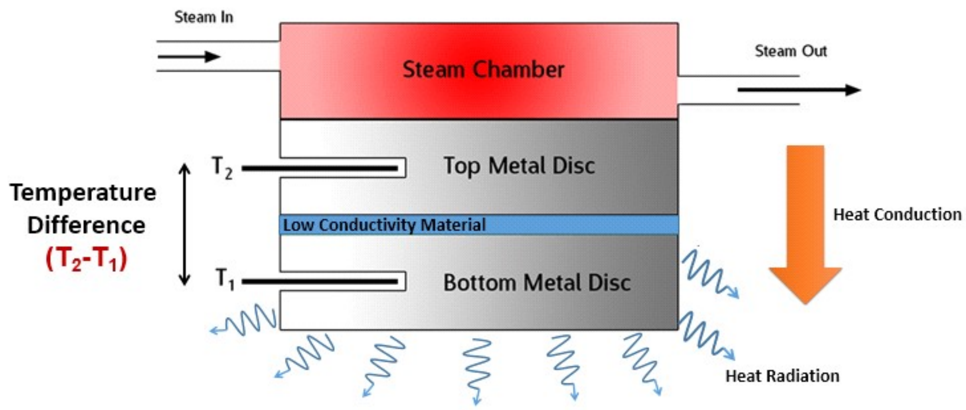


Fig. 2

$$Q = \frac{kA(T_2 - T_1)}{x} = ms\left({}^{dT}/_{dt}\right)$$

$$k = \frac{ms\left({}^{dT}/_{dt}\right)x}{A(T_2 - T_1)}$$

Where,

k - Thermal Conductivity of the Sample

A - Surface Area of the Sample Disc

T_2 - T_1 - Temperature Difference across the Sample

x - Thickness of the Sample Disc

'***m***' and '***s***' are the Mass and Specific Heat of the Bottom Disc.

NOTES

Aim – To calculate the thermal conductivity of a given bad conductor using Lee's and Charlton's methods.

Apparatus – A Steam Chamber, Two Metal Discs, a Bad Conductor in the Form of a Disc, a Burner, a Water Container, Rubber Pipe, 2 Thermometers, 1 Stopwatch, a Screw Gauge, and a Measuring Balance.

Diagram

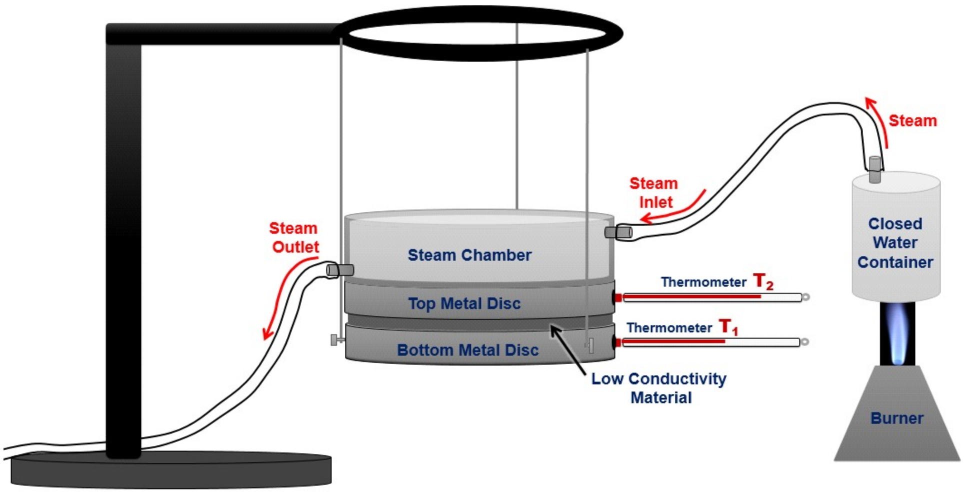


Fig. 3

Procedure

1. Determine the thickness (x) of the bad conducting material disc using a screw gauge (Refer Table 1). Determine the diameter and then calculate the area (A) using Vernier Calipers (Refer Table 2).
2. Arrange the apparatus as shown in the Figure (2) and start passing steam from the steam chamber.
3. Note down the temperature of the top ($è_2$) and bottom metal discs ($è_1$) after every 2 minutes (Refer Table 3) until they reach a steady-state and do not change further. This may take 20-30 minutes. Note down this temperature as the steady-state temperature of the top (T_2) and bottom metal disc (T_1).
4. Now, Remove the 'Low Conductivity Material' and let the bottom plate heat to T_1 +10 °C.
5. Now remove the 'Top Metal Disc' and put the low conductivity material back on the bottom metal disc and observe the change in its temperature from T_1+10 to T_1-10 °C with respect to time (Refer Table 4).
6. Plot the cooling curve of the bottom metal disc and calculate the rate of cooling by calculating the slope (*dT/dt*) at temperature T_1.

NOTES

7. Finally, apply the formula,

$$k = \frac{ms\left(\frac{dT}{dt}\right)x}{A(T_2 - T_1)}$$

Here *m* and *s* are the Mass and the Specific Heat of the Bottom Metal Disc. x and A are the Thickness and Area of Low Conductivity Material Disc.

Result: The thermal conductivity of a given poor conductor by Lee's and Charlton's method is found to be…………………...$Wm^{-1}K^{-1}$

Tables

Table 1 for the Thickness of Bad Conductor Disc

Least Count (LC) of the Screw Gauge …………..

Sr. No.	Main Scale Division	Circular Scale Division	MSD + (CSD × LC)
1.			
2.			
3.			
		Mean Thickness -	

Table 2 for the Diameter of Bad Conductor Disc

Least Count (LC) of the Vernier Calipers …………..

Sr. No.	Main Scale Division	Circular Scale Division	MSD + (CSD × LC)
1.			
2.			
3.			
		Mean Diameter (d) -	

Area of the Disc - π(d/2)2 = …………………….

Table 3 for Getting the Steady-State

Sr. No.	Temperature of Upper Metal Disc (θ_2)	Temperature of Lower Metal Disc (θ_1)
1.		
2.		
3.		
4.		
5.		
…		
…		

Table 4 for the Rate of Cooling

Sr. No.	Time (Minute)	Temperature of Lower Metal Disc
1.	1	
2.	2	
3.	3	
4.	4	
5.	5	
…		
…		

EXPERIMENT 14: Determination of Stefan's Constant

NOTES

Introduction

A black body is defined as the object which absorbs all the radiations falling on it. Therefore the absorptive power of a black body is one. Additionally, a black body can emit all the wavelengths and the Maxima of this spectrum depends upon the temperature of the body.

The emissive power officer face is defined as the energy emitted per second by per unit area. Stephen's law states that the rate of emission of energy per unit area of a black body is proportional to the fourth power of its Absolute Temperature.

$$E \propto T^4 \qquad ...(1)$$

$$E = \sigma T^4 \qquad ...(2)$$

Here σ is called as the Stefan's constant. Its value is 5.67×10^{-8} $Js^{-1}m^{-2}K^{-4}$. It was further modified by Boltzmann by taking into account the surrounding temperature and it was modified to

$$E = \sigma (T^4 - T_o^4) \qquad ...(3)$$

Theory

The enclosure B is at a constant temperature (T_0 K) and the disc D is attached to it. The enclosure and disc behave like a black body. Let the temperature of the disc is T K. The disc absorbs the radiation from B. Its rate of emission is different from its rate of absorption.

The rate of the gain of the energy of the disc = $\sigma (T^4 - T_o^4)$ A J/sec = $\frac{\sigma (T^4 - T_o^4) A}{J}$ cal/sec. Here A is the upper surface area of the disc and J is the mechanical equivalent of heat.

Let m and s denote the mass and specific heat of the disc material and $\frac{dT}{dt}$ is the rate of change in its temperature. Therefore, the heat gained by the disc per unit time can be expressed as, $ms \frac{dT}{dt}$.

Now on equating the two expressions we get,

$$\frac{\sigma (T^4 - T_o^4) A}{J} = ms \frac{dT}{dt} \qquad ...(4)$$

Here, in this formula we need to calculate the value of T, T_o, A, m and .

NOTES

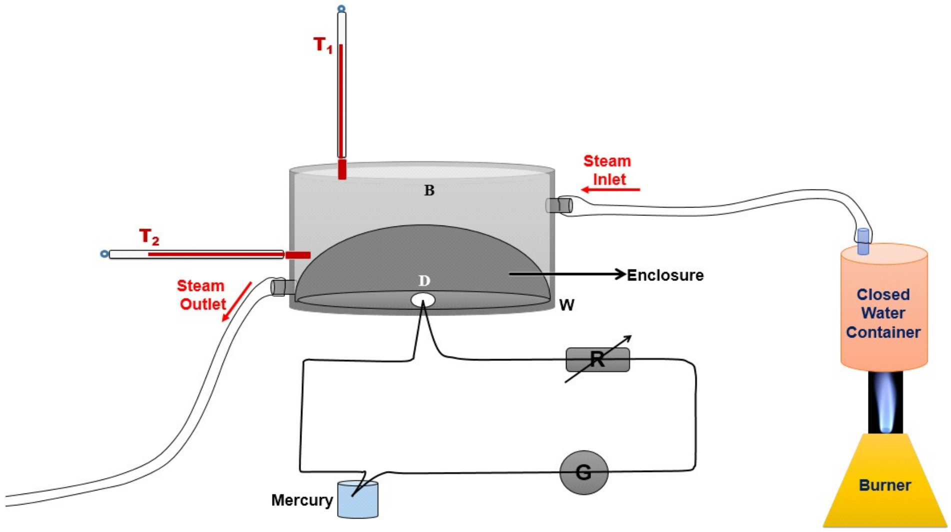


Fig. 1

Aim – To determine the value of Stefan's constant.

Apparatus – Stefan's Constant Apparatus, Thermometer, a Sensitive Galvanometer (Spot Galvanometer), Copper-Constantan Thermo-Couple, Metal Beaker with Sand, Steam Generator, Resistance Box, Test Tube, Mercury, Connecting Wires.

Procedure

Calibration of the Thermocouple

1. Insulate the disc D using the cotton wool when one junction of the thermocouple is attached to this. The disc D acts as a cold junction. Consider the temperature of this disc to be equal to the Room Temperature (RT).
2. Place the other junction of the thermocouple in a test-tube containing mercury, which is placed in a sand-bath. Heat it to 100 – 120 ^{o}C and note down its temperature using a thermometer.
3. Make connections and adjust the deflection in spot galvanometer within its range by varying the resistance in series.
4. Now allow the hot junction to cool and note down the deflection in galvanometer with the decrease in temperature of the hot junction, till room temperature (Refer Table 1).
5. Plot a graph between the temperature of the hot junction along the x-axis and the deflection of the galvanometer along the y-axis (Refer Figure 2).
6. Calculate its slope, which is and then reciprocate it.

NOTES

Determination of Other Temperature Variables

1. In this part, disc D behaves as a hot junction. First, take out the disc D and close the hole with some cotton wool.
2. Pass steam into the steam chamber. The temperature of the chamber will rise. When the temperature in two thermometers T_1 and T_2 becomes steady then record the temperature (in Kelvin) and take mean. This gives the average temperature of the enclosure T'.
3. Keep the other junction at room temperature.
4. Now remove the cotton from the hole and fit the disc in this. As the temperature of the disc increases the deflection in the galvanometer also increases. Note down the deflection of the galvanometer at a regular interval of 10 sec.
5. Calculate the Mass 'm' and Diameter 'd' of the given disc.
6. Plot the graph between time (t) along the x-axis and corresponding deflection (x) along the y-axis. Choose a point P on the graph close to the origin and draw a tangent to the curve at this point to calculate . Note down the deflection (x_1) corresponding to the point P (Refer Figure 3). Thereafter, note down the temperature T corresponding to the deflection x_1 (Refer Figure 2).
7. Calculate by multiplying and
8. Calculate Stefan's constant using Equation 4.

Observations

Mean Temperature of the Enclosure (T_o) = …………………… K

Least Count of the Spot Galvanometer = ……………........... cm

Mass of the Disc = ………………...........................……… g

Diameter of the Disc = ……………………............……… m

Area of the Disc = ……………………............……….…..... m^2

Specific Heat of the Disc = ……………….............……….. Cal g^{-1} K^{-1}

Table 1

For Calibration (Disc as Cold Junction)

Sr. No.	Temperature of Hot Junction (°C)	Temperature of Hot Junction (K = °C + 273)	Deflection x (cm)
1.			
2.			
3.			
4.			
…			
…			
…			

NOTES

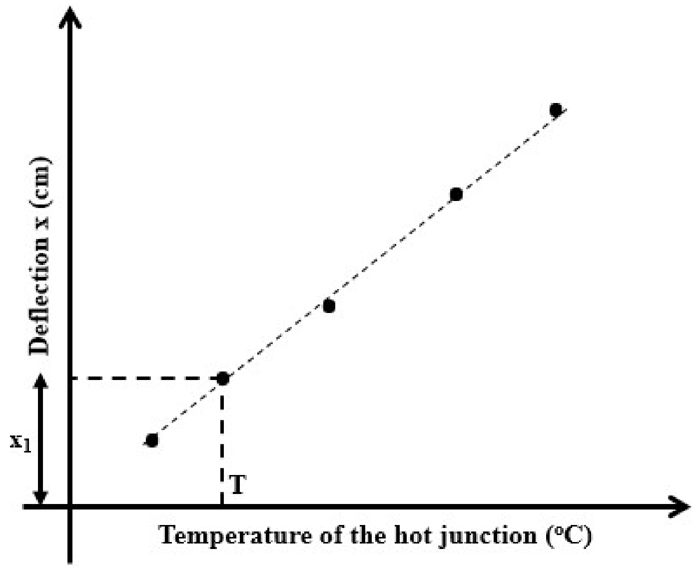


Fig. 2

Table 2

For T and (Disc as Hot Junction)

Sr. No.	Time t (sec)	Deflection x (cm)		Sr. No.	Time t (sec)	Deflection x (cm)
1.				…		
2.				…		
3.				…		
…				…		
…				…		
…				…		
…				…		

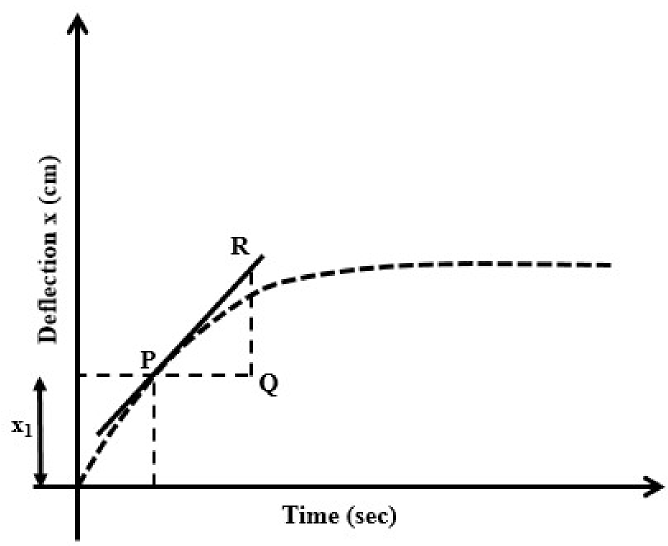


Fig. 3

Stefan's Constant = ………………………….. $Js^{-1}m^{-2}K^{-4}$

% Error in Measurement = $\frac{\text{Observed Value} - \text{Standard Value}}{\text{Standard Value}}$

NOTES

Precautions and Source of Errors

1. The junctions of the thermocouple should be clean and properly soldered.
2. The hot junction should be at a considerable distance from the cold junction.
3. The point P should be chosen close to the origin and tangent should be drawn carefully.
4. All the wire connections must be tight.

EXPERIMENT 15: Determination of B_H and m using Magnetometer

Introduction

The horizontal component of the Earth's Magnetic Field (B_H) is the component of the Earth's magnetic field along the horizontal surface perpendicular to the vector which passes through the center of the Earth. The horizontal component is measured in Tesla, *T*.

The Magnetic Dipole Moment (*m*) of a magnetic dipole is the property of the dipole, by which it aligns the magnetic dipole parallel to the external magnetic field. *m* is measured in Ampere-Square meters (Am^2).

Theory

Let us consider a bar magnet of magnetic moment *m*, which is suspended horizontally in a region where there are two horizontal magnetic fields perpendicular to each other. One is the horizontal component of the earth's magnetic field, $B_{H,}$ and the other is the externally applied magnetic field, *B*. In absence of the external magnetic field *B*, the bar magnet will align itself with the Earth's magnetic field. The external magnetic field causes a torque, τ_D (Deflecting Torque) to the deflection magnetometer. If è is the angle of deflection, then the magnitude of the deflecting torque will be,

$$\tau_D = mB\ cos\theta \qquad ...(1)$$

The bar magnet experiences a restoring torque τ_R due to the earth's magnetic field B_H, and its magnitude is given by,

$$\tau_R = mB_H\ sin\theta \qquad ...(2)$$

At equilibrium, both torques are equal and opposite to each other, and hence,

$$\tau_D = \tau_R \qquad ...(3)$$

$$mB\ cos\theta = mB_H\ sin\theta \qquad ...(4)$$

$$B = B_H\ tan\theta \qquad ...(5)$$

The above relation is known as tangent law. It gives the equilibrium orientation of a magnet suspended in a region with two horizontal magnetic fields perpendicular to each other.

NOTES

Vibration Magnetometer

The equation of motion of the bar magnet attached in the magnetometer, oscillating under the effect of restoring torque availed by the Earth's magnetic field is,

$$I\frac{d^2\theta}{dt^2} + mB_H\, sin\theta = 0 \qquad ...(6)$$

Thereafter, its period of oscillation for small è, is approximately,

$$T = 2\pi\sqrt{\frac{I}{mB_H}} \qquad ...(7)$$

Where,

I = Moment of Inertia of the Magnet about the Axis of Oscillation

m = Magnetic Moment of the Magnet

B_H = Horizontal Intensity of the Earth's Magnetic Field.

For a rectangular bar magnet, it is given as,

$$I = M\frac{L^2 + b^2}{12} \qquad ... (8)$$

Where,

M = Mass of the Magnet

L = Length of the Magnet (Longest Horizontal Dimension)

b = Breadth of the Magnet (Shortest Horizontal Dimension)

Now, squaring Equation (7) both sides, we get,

$$T^2 = 4\pi^2\frac{I}{mB_H} \qquad ...(9)$$

Which gives us,

$$mB_H = 4\pi^2\,\frac{I}{T^2} \qquad ...(10)$$

Thus, by measuring the Period *T of the Oscillating Needle*, mB_H can be determined.

Working Principle

Tan-A Position

In Tan-A position (Refer Figure 1), firstly, rotate the compass box such that the (0-0) line is parallel to the length of the magnetometer. Thereafter, rotate the whole wooden structure till the aluminum needle pasted perpendicular to the magnet

(which is aligned in the North-South direction) reads (0-0). Finally, the bar magnet (the same one that was previously suspended in the Vibration Magnetometer) is placed horizontally, at a distance, d, parallel to the arm of the deflection magnetometer, so that the deflection of the aluminum pointer is around 30° to 60°.

NOTES

The bar magnet is a magnetic dipole. Equivalent to an electric dipole, there are two magnetic poles *P* (in reality no magnetic monopole can exist), separated by a distance $L = 2l$. Analogous to an electric dipole, we would have a field for each pole.

$$B = \frac{\mu_0}{4\pi}\frac{P}{r^2} \quad ...(11)$$

And a magnetic dipole moment

$$m = P.(2l) \quad ...(12)$$

$$B = \frac{\mu_0 P}{4\pi}\left[\frac{1}{(d-l)^2} - \frac{1}{(d+l)^2}\right] = \frac{\mu_0 P}{4\pi}\frac{2md}{(d^2-l^2)^2} \quad ...(13)$$

Where,

m - Magnetic Moment of the Magnet

μ_0 - Magnetic Permeability of Free Space ($4\pi \times 10^{-7}\ TmA^{-1}$)

θ - Deflection of the Pointer

Therefore, by the Tangent Law at Equilibrium,

$$B_H \tan\theta = \frac{\mu_0 P}{4\pi}\frac{2md}{(d^2-l^2)^2} \quad ...(14)$$

Solving for m/B_H we get,

$$\frac{m}{B_H} = \frac{\mu_0}{4\pi}\frac{(d^2-l^2)^2}{2d} \times \tan\theta \quad ...(15)$$

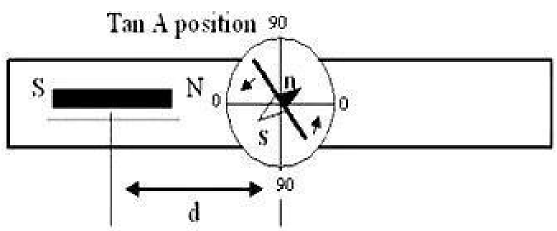


Fig. 1

Tan-B Position

In this position (Refer Figure 2), initially, the compass box is rotated so that the (90-90) line is parallel to the length of the magnetometer. Thereafter, the magnetometer is rotated so that the aluminum pointer reads (0-0). Finally, the magnet is horizontally placed, perpendicular to the length of the magnetometer, at

a distance *d,* such that the deflection of the aluminum pointer is between 30° to 60°.

The magnetic field perpendicular to the magnetic dipole is given by,

NOTES

$$B = B_N sin\alpha + B_s sin\alpha = \frac{2\mu_0 P}{4\pi}\left(\frac{1}{(d^2+l^2)}\ \frac{l}{(d^2+l^2)^{1/2}}\right) \quad ...(16)$$

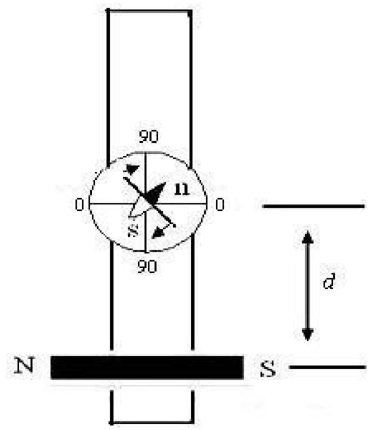


Fig. 2

Therefore, the field due to the bar magnet at the center of the compass is,

$$B = B_H tan\theta = \frac{\mu_o}{4\pi}\frac{m}{(d^2+l^2)^{3/2}} \quad ...(17)$$

Which leads to,

$$B = B_H tan\theta = \frac{\mu_o}{4\pi}\frac{m}{(d^2+l^2)^{3/2}} \quad ...(18)$$

$$\frac{m}{B_H} = \frac{4\pi(d^2+l^2)^{3/2}}{\mu_o} \times tan\theta \quad ...(19)$$

The value of is can be calculated by averaging the values obtained from Equations 15 and 19. Now using this value with Equation 10 we can calculate *m* and B_H.

Aim – To determine the Horizontal Intensity (B_H) of the Earth's Magnetic Field and the Magnetic Dipole Moment (*m*) of a Bar Magnet using a Deflection Magnetometer.

Apparatus – Deflection Magnetometer, a Wooden Board of around One Meter Long, Stopwatch, Bar Magnet.

Procedure

***To Determine* m.B$_H$**

1. Draw the direction of the horizontal component of the Magnetic Field (B_H) on the table using a compass.

NOTES

2. Place the vibration magnetometer parallel to the North-South direction.
3. The bar magnet is then suspended horizontally in the vibrating magnetometer with its North Pole pointing towards the North Direction. The magnet is then set into vibration by bringing another bar magnet near to it.
4. Determine the time taken for 10 oscillations twice and the mean of t is to be found and period of oscillation (T) can be calculated by dividing this time by 10.
5. The mass of the magnet is determined. The length and breadth of the magnet are measured by using Vernier Caliper to calculate its moment of inertia using Equation 8.
6. Furthermore, the value of mB_H is calculated using Equation 10.

To Determine m/B_H

Tan A Position

1. The compass box alone is rotated so that the (0-0) line is parallel to the arm of the magnetometer.
2. Then the apparatus as a whole is rotated till the aluminum pointer reads (0-0).
3. The bar magnet is placed horizontally, parallel to the arm of the deflection magnetometer, at a distance, d from the center of the compass needle, chosen so that the deflection lies between 30° and 60°. Thereafter, observe the reading of the ends of the pointer.
4. The magnet is then reversed at the same position and then again observe the readings of the pointer.
5. The magnet is then transferred to the other arm of the magnetometer, keeping it at the same distance *d*, four more deflections are noted as before.
6. The experiment is repeated for different values of *d* and an average value for m/B_H is calculated using Equation 15.

Tan B Position

1. The compass box alone is rotated so that the (90-90) line is parallel to the arm of the magnetometer. Then the magnetometer as a whole is rotated so that the pointer reads (0-0).
2. The magnet is placed horizontally, but perpendicular to the arm of the magnetometer. Repeat the whole process as before, to get a second average value of m/B_H using Equation 19, which is combined into an overall average with the first.

NOTES

Table 1

Time for 10 Oscillations (s)		Period T = t/10 (s)	
1	2		

$$I = M\frac{L^2 + b^2}{12} = \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots$$

$$m\,B_H = 4\,\pi^2\,\frac{I}{T^2} = \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots$$

Table 2

Position	Distance d (m)	Deflection θ									m/B_H
		θ_1	θ_2	θ_3	θ_4	θ_5	θ_6	θ_7	θ_8	θ	
tan A											
tan B											

$$mB_H = x$$

$$\frac{m}{B_H} = y$$

Then, $m = \sqrt{xy} = \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots$ **Am^{-2}**

$$B_H = \sqrt{\frac{x}{y}} = \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{ Wbm}^{-2}$$

Results

The Horizontal Intensity of Earth's Magnetic Field (B_H) = ……….. Wbm^{-2}

The Moment of the Bar Magnet (m) = ……………………………. Am^{-2}

Precautions and Source of Errors

1. Always measure the distance from the center of the magnet.
2. The arm of the wooden stand should be parallel to the horizontal component of the magnetic field.
3. Place the bar magnet in proper orientation otherwise, it may add errors in measurement.
4. The motion of the needle in the magnetometer should be smooth.

EXPERIMENT 16: Fabry-Perot Interferometer

Introduction

The Fabry-Perot interferometer uses the phenomenon of multiple beam interference that arises when light shines through a cavity bounded by two reflective parallel surfaces. Each time the light encounters one of the surfaces, a portion of it is transmitted out, and the remaining part is reflected back. The net effect is to break a single beam into multiple beams which interfere with each other. If the additional

optical path length of the reflected beam (due to multiple reflections) is an integral multiple of the light's wavelength, then the reflected beams will interfere constructively. More is the number of reflection inside the cavity, sharper is the interference maximum. Using Fabry-Perot (FP) interferometer as a spectroscopic tool, concepts of finesse and free spectral range can be understood.

NOTES

Aim – (i) Alignment of Fabry-Perot Interferometer to observe Concentric Circular Fringes (ii) Measurement of the Wavelength of a Diode Laser

Apparatus – Optical Rail, Fabry-Perot Setup, Movable Mirror with Fine Linear Micrometer (-mm), Diode Laser with Kinematic (5 V) Power Supply, Achromatic Lens Mount, Frosted Glass viewing Screen and Mount with Micrometer.

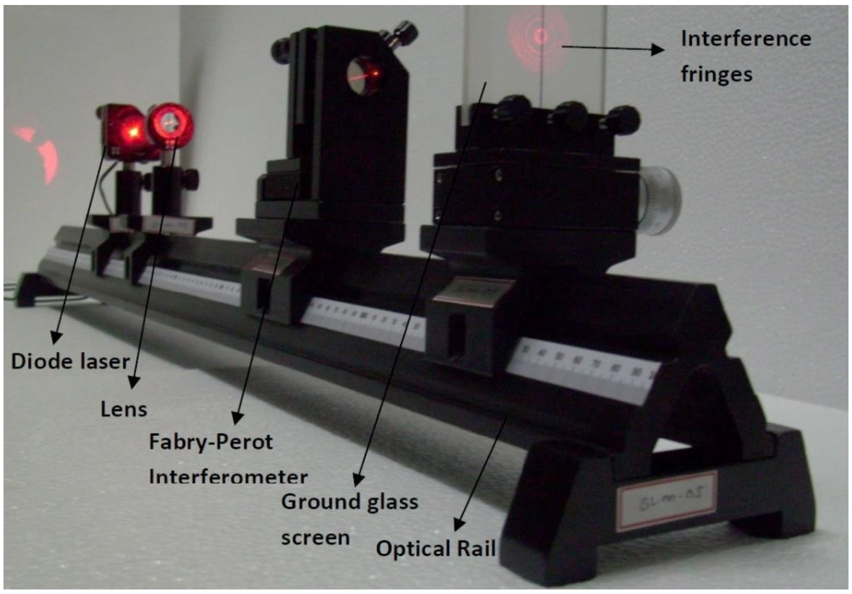


Fig. 1 *Fabry-Perot Setup*

Theory

The Fabry-Perot interferometer works on the principle which is schematically explained in the below given Figure 2.

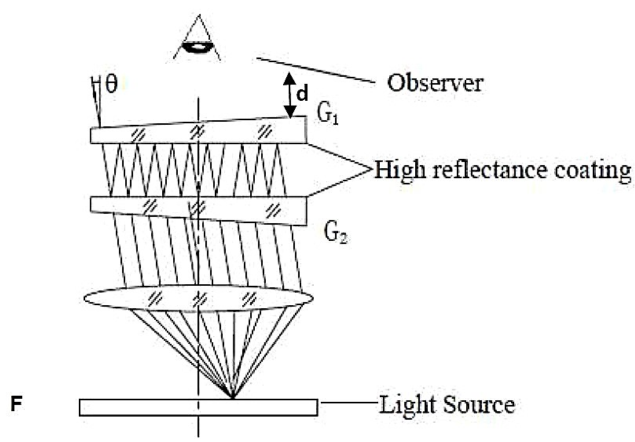


Fig. 2 *Schematics of Fabry-Perot Interferometer*

NOTES

The two partially mirrors G1 and G2 aligned parallel to each other at a distance d, forming a reflective cavity. When a monochromatic light (a laser here) of wavelength ë is irradiated at an incident angle è, multiple reflections occurs inside the cavity. The part of the light is transmitted each time the light reaches the second cavity. All such transmitted light rays interfere with each other to give rise to maxima and minima depending on the path difference between them. Let n be the refractive index of the medium in the cavity (in this case, air). Then the optical path difference between two neighbouring rays is:

$$\Delta = 2nd\cos\theta \qquad ...(1)$$

And the phase difference is given by, $d = \frac{2\pi}{\lambda}\Delta$ ...(2)

The below given Figure 3 provides calculation of the path difference for a general cavity, where α And β are the angles of incidence and refraction, respectively.

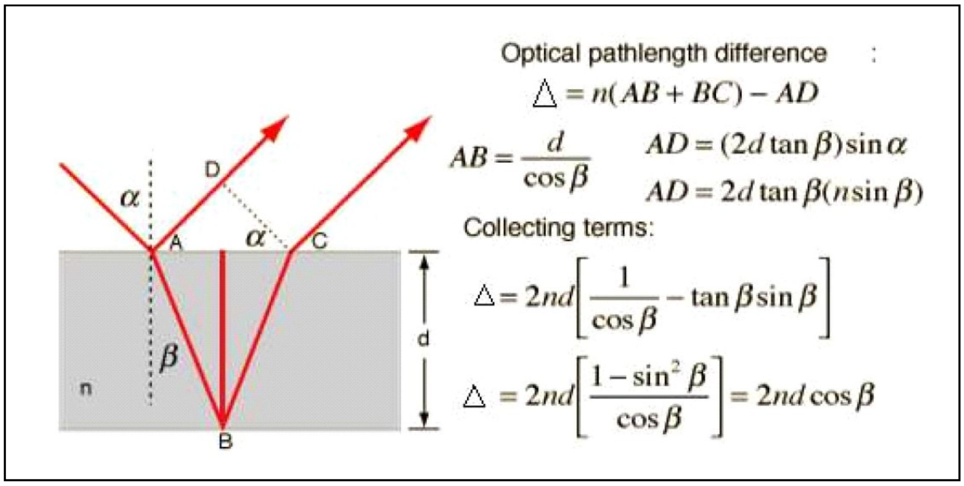


Fig. 3 *Calculation of Path Difference*

Thus, the transmitted light ray intensity IT is given by:

$$I_T = I_o \frac{1}{1 + \frac{4R}{(1-R)^2}\sin^2\frac{\delta}{2}} \qquad ...(3)$$

Where, *I0* is the incident intensity, R is the reflectivity of the mirrors. It can be noticed that *IT* varies with α.

I_T is maximum when **Δ = m λ (m = 0, 1, 2…) or α = 2mπ** …(4)

and minimum when **Δ = (2m+1) λ/2 (m = 0, 1, 2…) or δ = (2m + 1)π** …(5)

The complete interference pattern appears as a set of concentric rings. The sharpness of the rings depends on a parameter called coefficient of finesse, F, defined as, $F = \frac{4R}{(1-R)^{2^*}}$

Determination of λ : Using the relations 1 and 4 (or 5) wavelength of the incident light can be determined accurately. Let the initial separation between the mirrors is d_1. If one counts the number of fringes (say maxima) appearing or disappearing at the centre $(\theta \approx 0)$ by varying the distance between the mirrors to d_2, then λ can be determined as follows:

NOTES

$$2d_1 = m1\ \lambda_1 \quad ...(6)$$

$$2d_2 = m2\ \lambda_2 \quad ...(7)$$

$$m_2 - m_1 = \text{Number of Maxima}$$

$$\lambda = \frac{2(d_2 - d_1)}{(m_2 - m_1)} \quad ...(8)$$

Procedure

I. Alignment of Fabry-Perot Interferometer to observe Concentric Circular Fringes

1. Mount and lock the diode laser on the optical rail towards one end.
2. Mount the Fabry-Perot interferometer towards the middle of the optical rail (about 40 cm from laser). It has one fixed and one movable mirror.
3. Adjust the three screws behind the movable mirror to make sure that the two mirrors are visibly parallel to each other approximately and the distance between them is about 2 mm.
4. Mount the ground glass screen at the other extreme end.
5. Switch on the diode laser and adjust it such that the beam passes through the centre of the two mirrors. Adjust the two black screws (for movement in x and y directions) behind the movable mirror to let the multiple reflected beams coincide on the screen. It means both the mirrors are now nearly parallel.
6. Place a lens (f = 100 mm) in front of the laser to expand the beam to create a broad source. Adjust the position of the lens so that the entire reflection cavity is illuminated. With all the components perfectly set, the observer can find a series of very intense, concentric circular interference rings on the ground glass screen.

II. Measurement of the Wavelength of a Diode Laser

1. Setup the F-P interferometer as described above to observe clear circular fringes at the centre of the ground glass screen.
2. Determine the least count of the micrometer screw attached to the movable mirror. Record the reading d1 of the fine micrometer
3. Turn the micrometer slowly and count the number of fringes that appear (or disappear) at the centre of the ground glass screen. Keep on recording the micrometer reading d2 after every count 50 fringes.

4. Acquire enough data and fill up the observation table. Plot a suitable graph to get a straight line. Find slope of the graph using Equation 8 to determine ë.

NOTES

Observation Table

Least Count of Micrometer = ……

Initial Position of Micrometer d_1 = …….

Sl. No.	No. of Fringes Appeared/Disappeared ($m_2 - m_1$)	No. of Divisions Rotated on Micrometer	$d_2 - d_1$ (cm)
1	50		
2	100		
3	150		

From the graph using Least Square Fit, find Slope ….

Calculations ; = ……..

Precautions

1. Do not touch or contact in any way either the front or back surfaces of the mirror pieces. Doing so will permanently damage the mirror coatings.
2. Avoid eye exposure to the direct laser beam.
3. Move the micrometer screw very slowly.

EXPERIMENT 17: Hydrogen Spectra

Introduction

Before the dawn of Quantum Mechanics in the 19th Century, many physicists devoted to extensively towards the field of spectroscopy in hope to figure out some physical properties of atoms and molecules by investigating the electromagnetic radiation emitted or absorbed by them. Several atomic and molecular spectra have been studied in detail and amongst them the emission spectra of the hydrogen which is relatively simple were most intensely studied.

Theoretical Background

According to Bohr's model of hydrogen atom, the wavelengths of Balmer series spectral lines are given by,

NOTES

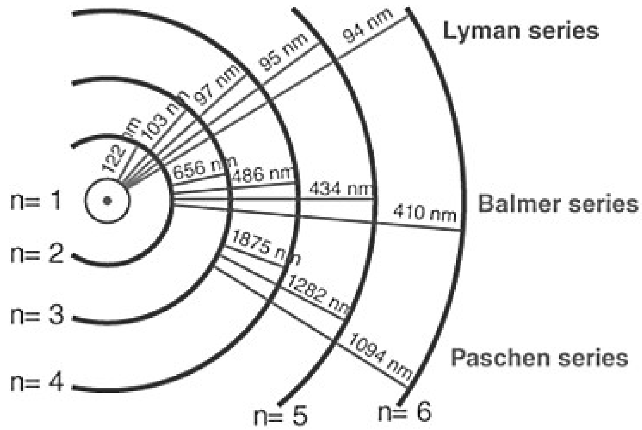


Fig. 1 *Emission Spectra of Hydrogen*

$$\frac{1}{\lambda} = R_y\left[\frac{1}{n^2} - \frac{1}{m^2}\right] \qquad ....(1)$$

(1)

where, $n = 2$ and $m = 3, 4, 5, 6$ … and *Rydberg's* constant R_y is given by

$$R_y - \frac{e^4 m_e}{8\varepsilon_0^2 h^3 c} = 1.097 \times 10^7 m^{-1} \qquad ....(2)$$

Where 'e' is the charge of 1 electron, 'm_e' is mass of one electron, 'ε_0' is permittivity of air = 8.85×10^{-12}, 'h' is Planck's constant and 'c' is velocity of light. The wavelengths of the hydrogen spectral emission lines are spectrally resolved with the help of a diffraction grating. The principle is that if a monochromatic light of wavelength λ falls normally on an amplitude diffraction grating with periodicity of lines given by 'g' (= 1/N, where N is the number of grating lines per unit length), the intensity peaks due to principal maxima occur under the condition:

$$g \sin \alpha = p\lambda \qquad ...(3)$$

Where 'α' is the diffraction angle and $p = 1, 2, 3, \ldots$ is the order of diffraction.

In the first part of the experiment, the grating constant 'g' is determined by measuring the diffraction angles for the known spectral lines of a Mercury (Hg) Spectral Tube (Mercury Vapour Lamp). The Hg spectral tube is then replaced by a Hydrogen (Atomic) Spectral Tube, in which, H_2 is converted into atomic hydrogen due to collision ionization. The electrons in H atoms are excited to higher energy levels through collisions with other electrons. When these electrons return to lower energy levels, the atom emits electromagnetic radiation of discrete frequencies in various spectral ranges. Balmer's series spectral lines fall in ultraviolet and visible ranges and the latter wavelengths are determined in this experiment by measuring the corresponding diffraction angles. Usually, only first order diffraction is studied, for which the value of 'p' in Equation 2 is taken to be unity.

Aim: To measure the wavelengths of visible spectral lines in Balmer Series of Atomic Hydrogen and to determine the value of Rydberg's Constant.

Apparatus

NOTES

The apparatus is shown in Figure 1 and consists of—(1) Pasco Model SP-9268 Precision Student Spectrometer, (2) Grating with either 300 lines/mm or 600 lines/mm, (3) Hydrogen Discharge Lamp and Power Supply, (4) Magnifying Glass, (5) Small Night Light, and (6) Black Cloth to Block Out Stray Light.

Experimental Set-Up

The experimental set-up is shown in Figure 2. Hydrogen or mercury spectral tubes are used as the source of light. The spectral tube is fixed between two high voltage electrodes. A grating and a spectrometer will be used to analyse different spectra.

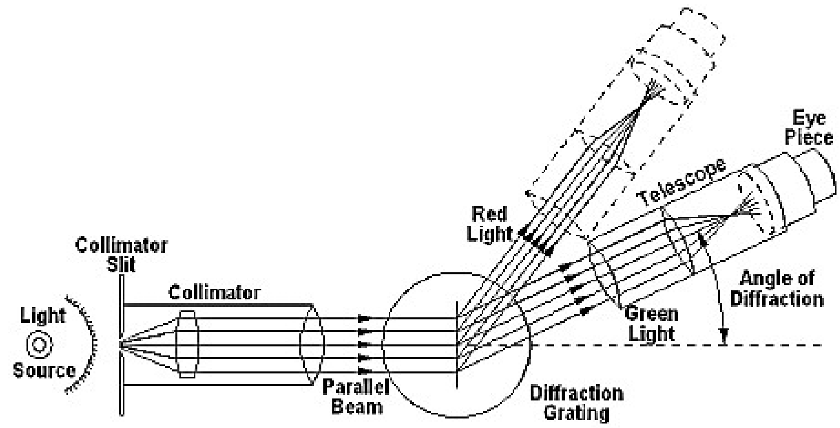


Fig. 2 *Schematic Diagram of Student Spectrometer*

First, a mercury source is used to determine the grating element (g). Then using this value of g and a hydrogen spectral tube the unknown lines of Balmer series of hydrogen spectra can be determined.

Procedure

A. Adjusting the Spectrometer

Follow the support manual for spectrometer provided in the appendix for basic adjustment of spectrometer. Determine the vernier constant of the spectrometer. Fix the grating on the prism table. Do not disturb the spectrometer henceforth throughout the experiment.

B. Determination of g

1. Bring in the Hg source close to the collimator of the previously leveled spectrometer.
2. Then switch ON the power supply and let the Hg (Mercury) lamp warm up.

3. Look through the telescope to notice the three first order spectral lines of Hg (Yellow, Green and Blue) on both sides of the direct image of the slit at the center. Make the spectral lines vertical by turning the grating slightly in its plane.
4. Note down the positions of the cross wire for each line on one side using the two verniers on the spectrometer. Use a torch, if needed, to read the Vernier's Scale.
5. Repeat the above step by turning the telescope to the other side too. Determine the Diffraction Angle (α) for all the three spectral lines of Hg spectrum. Using the spectral data of Hg given below, calculate g.
6. Switch OFF the power supply and remove the Hg spectral tube.

NOTES

C. Studying Hydrogen Spectrum

1. In presence of the instructor/lab operator bring in the hydrogen source to the front of collimator. Then switch ON the power supply.
2. Repeat Steps B.3 to B.4 (mentioned above) and note down the positions of the cursors for 3 spectral lines (Red, Green and Violet) of the hydrogen spectrum.
3. Using the value of g determined earlier, calculate the wavelength of each of the spectral lines.
4. Switch OFF hydrogen spectral tube.

Observation

Table 1: Determination of *g*

Colour/ λ(nm)	Left side						Right side						Vernier 1 2θ(deg)	Vernier 2 2θ(deg)	Avg. θ(deg)	g
	Vernier 1(deg)			Vernier 2(deg)			Vernier 1(deg)			Vernier2(deg)						
	MSR	VSR	TOTAL	MSR	VSR	TOTAL	MSR	VSR	TOTAL	MSR	VSR	TOTAL				

Mean value of *g* =-------

Table 2: Determination of spectral lines of hydrogen

Colour/ Line/ Literature Value (nm)	Left side						Right side						Vernier 1 2θ(deg)	Vernier 2 2θ(deg)	Avg. θ(deg)	λ (nm)
	Vernier 1(deg)			Vernier 2(deg)			Vernier 1(deg)			Vernier2(deg)						
	MSR	VSR	TOTAL	MSR	VSR	TOTAL	MSR	VSR	TOTAL	MSR	VSR	TOTAL				
Red/H_α/656.28																
Green/H_β/486.13																
Violet/H_γ/434.05																

NOTES

Results and Analysis

1. Assign appropriate values of n and m (n = 2 and m = 3, 4 ...) to each λ (average value). Tabulate the values of n and m, the corresponding values of $(1/n^2-1/m^2)$ and 1/λ.
2. Plot 1/λ vs. $(1/n^2 -1/m^2)$ on a graph sheet. Indicate the error bars of (1/5λ) by Calculating $1/(\lambda \pm \Delta\lambda)$ in each case. Indicate n and m for the three data points on the graph.
3. Draw the linear graph. From the slope of the graph and the error in the slope, determine the value of Rydberg's constant and the corresponding random error. Write the final result with its uncertainty.

Precautions

1. Handle the spectral tube with utmost care.
2. Never touch the surface of the grating by hand. Always hold it from the sides.
3. Do not change the positions of the spectrometer and the spectral tube throughout the experiment.
4. Switch OFF power supply before making any changes in the spectral tube arrangement.

EXPERIMENT 18: To find out the Refractive Indices of Different Liquids using a Hollow Prism.

About Refractive Index

Introduction

The refractive index (also known as refraction index or index of refraction) of a material is a dimensionless number that describes how fast light travels through that material. For example, the refractive index of water is 1.33, meaning that light travels 1.33 times slower in water than in a vacuum. Increasing the refractive index corresponds to decreasing the speed of light in the material. A hollow prism filled with liquid can be used to determine the refractive index of that liquid.

Theory

A prism is a transparent optical element with flat, polished surfaces that refract light. A prism can be used to break light up into its constituent spectral colours. The hollow prism made from transparent including glass and have a cavity to fill liquid inside whose refractive index to be determined. When a beam of light strikes on the surface of transparent material (glass, water, quartz crystal, etc.), the portion of the light is transmitted and other portion is reflected. The transmitted light ray has small deviation of the path from the incident angle. This is called refraction. Refraction is due to the change in speed of light while passing through the medium. It is given by Snell's Law,

$$\frac{sin(i_1)}{sin(r_1)} = \frac{n_2}{n_1}, \quad ...(1)$$

NOTES

Where 'i' is the angle of incident, 'r' is the angle of refraction, n_1 is the refractive index of the first medium and n_2 is the refractive index of the second medium. When a ray of light passes through a prism, it suffers refraction as shown in Figure 1.

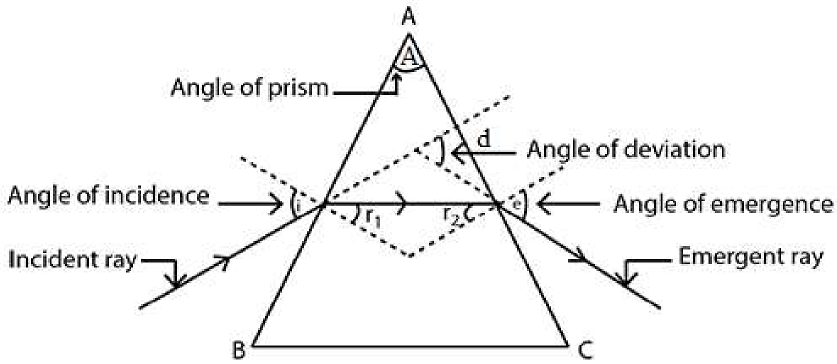


Fig. 1 *Refraction of Light by Prism*

We can apply Snell's Law to the ray of light at each surface. This leads to the two equations,

$$sini_1 = nsinr_1 \quad (2)$$

$$nsinr_2 = sini_2 \quad (3)$$

The angle r_1 and r_2 are not independent, being related by the equation,

$$A = r_1 + r_2, \quad (4)$$

In minimum deviation position, $\angle i_1 = \angle i_2$ and so $\angle r_1 = \angle r_2 = \angle r$ or

$$\angle i = \frac{A}{2} \quad (10)$$

Then from eq.(6) we have,

$$i_2 = (\text{d} + A)/2 \quad (11)$$

Substituting this into eq.(3) and solving for the index of refraction gives,

$$n = \frac{sin((\text{d} + A)/2)}{sin(A/2)} \quad (12)$$

The angle d is known as the minimum angle of deviation for the prism at the wavelength λ.

Aim: To find out the Refractive Indices of Different Liquids using a Hollow Prism.

Apparatus: A Spectrometer, a Spirit Level, a Source of Monochromatic Light (Sodium Vapor Lamp), a Magnifying Lens and a Reading Lamp, Hollow Glass

Prism, Various Liquids like Water, Carbon Disulphide, Bell Pins and Drawing Board.

Procedure

NOTES

(A) Telescope Adjustment

1. The spectrometer and the prism table are arranged in horizontal position by using the levelling screws (as shown in Figure 2).
2. The telescope is turned towards a distant object to receive a clear and sharp image.



Fig. 2 *Spectrometer*

3. The slit is illuminated by a sodium vapour lamp and the slit and the collimator are suitably adjusted to receive a narrow, vertical image of the slit.
4. The telescope is turned to receive the direct ray, so that the vertical slit coincides with the vertical crosswire.

(B) Measurement of the Angle of the Hollow Prism

1. Determine the least count of the spectrometer.
2. Place the prism on the prism table with its refracting angle 'A' towards the collimator and with its refracting edge 'A' at the centre. In this case some of the light falling on each face will be reflected and can be received with the help of the telescope (as shown in Figure 3).

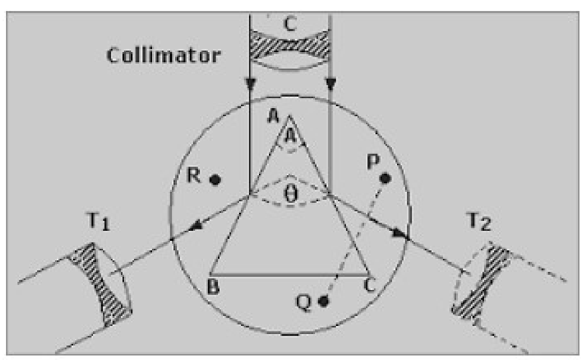


Fig. 3 *Arrangement to Determine the Angle of Prism*

NOTES

3. The telescope is moved to one side to receive the light reflected from the face AB and the cross wires are focused on the image of the slit. The readings of the two Vernier's are taken.
4. The telescope is moved in other side to receive the light reflected from the face AC and again the cross wires are focused on the image of the slit. The readings of the two verniers are taken.
5. The angle through which the telescope is moved; or the difference in the two positions gives twice of the refracting angle 'A' of the prism. Therefore half of this angle gives the refracting angle of the prism.

(C) Measurement of the Angle of Minimum Deviation

1. Place the prism so that its centre coincides with the centre of the prism table and light falls on one of the polished faces and emerges out of the other polished face, after refraction. The telescope is turned to view the refracted image of the slit on the other face (as shown in Figure 4).

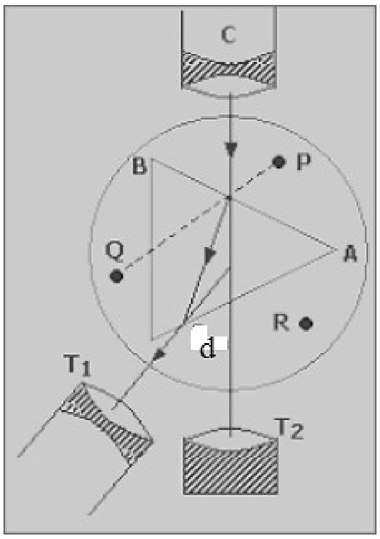


Fig. 4 *Arrangement to Determine the Angle of Minimum Deviation*

2. The Vernier Table is slowly turned in such a direction that the image of slit is move directed towards the directed ray; i.e., in the direction of decreasing angle of deviation.
3. It will be found that at a certain position, the image is stationary for some moment. Vernier Table is fixed at the position where the image remains stationary. Using telescope fine adjusting slider, make coincide the slit with cross wire.
4. Note corresponding main scale and vernier scale reading in both Vernier (Vernier I and Vernier II).

5. Carefully remove the prism from the prism table. Turn the telescope parallel to collimator, and note the direct ray readings.
6. Find the difference between the direct ray readings and deviated readings. This angle is called angle of minimum deviation (d). Refractive index of the liquid inside the hollow prism is determined by using Equation (12).

NOTES

Observations

1. Least Count of Spectrometer

   One Main Scale Division, N =. . . . . .degrees

   Number of Divisions on Vernier, v =. . . . . .

   Least Count= N /v =. . . . . .degrees =. . . . . .seconds

2. Wavelength of Light used = ...
3. Table for the angle of the prism (A):

S.No.	Vernier	*Telescope reading for reflection*						Difference $\theta = a - b$	$A = \theta/2$
		First face			Second face				
		MSR	VSR	TR(a)	MSR	VSR	TR(b)		
1.	V_1								
	V_2								
2.	V_1								
	V_2								
3.	V_1								
	V_2								

* MSR = Main Scale Reading, VSR = Vernier Scale Reading, TR = MSR+VSR×LC = Total Reading

Table for the angle of minimum deviation:

4.

S.No.	Vernier V_1			Vernier V_2		
	Telescope reading		Difference d	Telescope reading		Difference d
	Minimum deviation	Direct reading		Minimum deviation	Direct reading	
1.						
2.						

Results

1. Angle of Prism: . . . . degrees
2. Angle of Minimum Deviation of the Prism: . . . .
3. Refractive Index of the Liquid Filled inside the Prism: . . . .
4. Percentage Error: ....

Precautions

1. The telescope and collimator should be individually set for parallel rays.
2. Slit should be as narrow as possible.

3. Both Vernier's should be read.
4. The prism should be properly placed on the prism table for the measurement of angle of the prism as well as for the angle of minimum deviation.

NOTES

EXPERIMENT 19: Solar Cell

Introduction

The solar cell is device, which converts the solar energy into electrical energy. It is also called a photovoltaic cell. A solar panel consists of array of large numbers of solar cells connected in series or parallel. In a solar panel solar cell connected in a series to generate the desired output voltage while those connected in parallel to generate the desired output current. The solar panels are used to charge the lead acid or Nickel-Cadmium batteries instead of providing direct inputs to the electrical devices. During Sun the solar panel charges the battery and then electricity is supplied to devices through invertors or directly from battery depending upon the device is AC or DC, respectively.

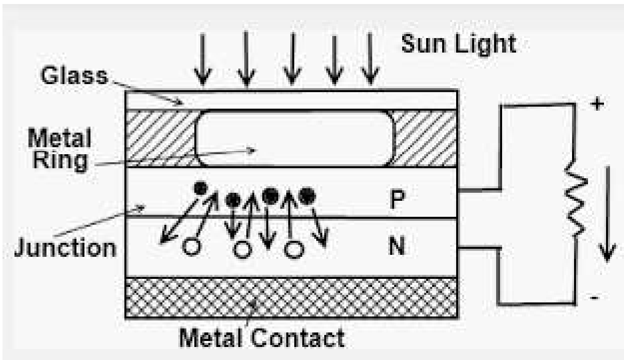


Fig. 1 *Working Principle of a Solar*

Theory

The operation of the solar cell is somewhat same as that of other junction photo detectors. There is a built-in depletion region without an applied reverse bias and when photons of sufficient energy fall on junction they create hole-electrons pairs. In the solar cell, as shown in Fig. 1a, the pair must diffuse a significant distance to reach the narrow depletion region to be drawn out as useful current. Hence, there is higher probability of recombination. The current generated by separated pairs increases the depletion region voltage (Photovoltaic effect). When a load is connected across the cell, the potential causes the photocurrent to flow through the load.

The E.M.F. generated by the solar cell in the open circuit, i.e. when no current is drawn from it is denoted by V_{OC} (V - Open Circuit). This is the maximum value of E.M.F. When a high resistance is introduced in the external circuit a small current flows through it and the voltage decreases. The voltage goes on falling and the current goes on increasing as the resistance in the external circuit is reduced. When the resistance is reduced to zero the current rises to its maximum value

known as saturation current and is denoted as I_{SC}, the voltage becomes zero. A V-I characteristic of a solar cell is shown in Figure 2.

NOTES

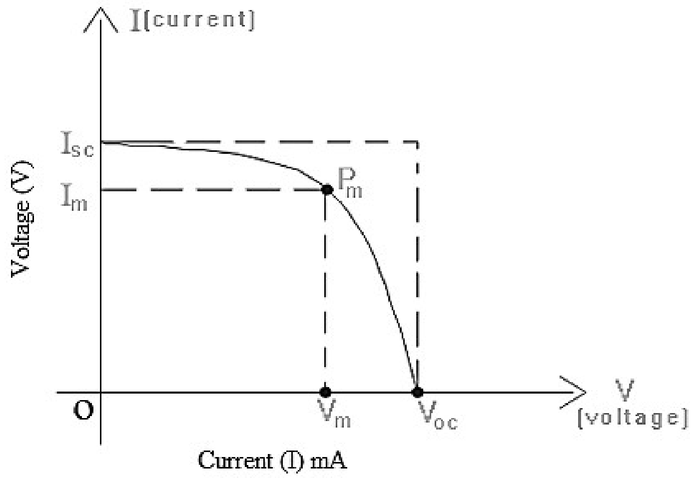


Fig. 2 *V-I Characteristics*

The product of open circuit voltage V_{OC} and short circuit current I_{SC} is known ideal power.

So,

Ideal Power = $V_{OC} \times I_{SC}$

The maximum useful power is the area of the largest rectangle that can be formed under the V-I curve. If V_m and I_m are the values of voltage and current under this condition, then,

Maximum Useful Power = Vm × Im

The ratio of the maximum useful power to ideal power is called the fill factor

Hence,

Fill Factor = $V_m \times I_m / V_{OC} \times I_{SC}$

AIM: To plot the V-I Characteristics of the Solar Cell and hence determine the Fill Factor.

APPRATUS: Solar cell mounted on the front panel in a metal box with connections brought out on terminals. Two meters mounted on the front panel to measure the solar cell voltage and current. Different types of load resistances selectable using band switch also provided on the front panel. Three single points and two interconnect able patch chords for connections. Wooden plank with half meter scale fitted on it and a lamp holder with 100 watt lamp.

CIRCUIT DIAGRAM

NOTES

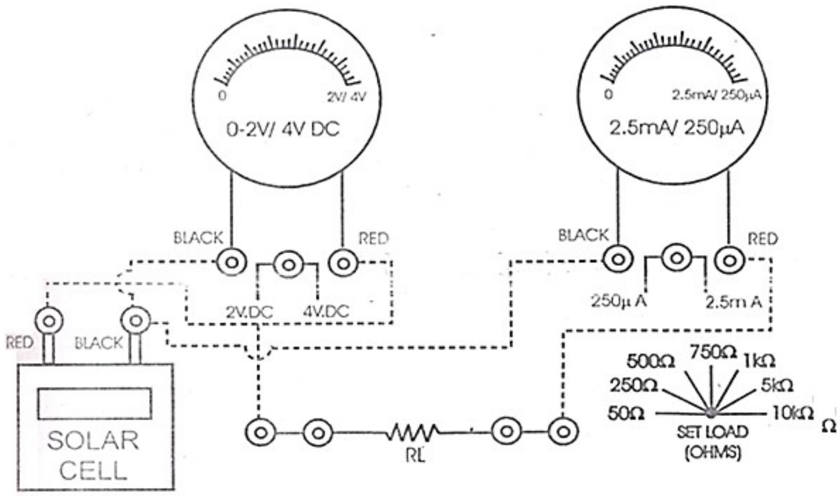


Fig. 2 *Solar Cell Characteristics Apparatus*

Procedure

When experiment is performed with 100 Watt Lamp

1. Place the solar cell and the light source (100 Watt Lamp) opposite to each other on a wooden plank. Connect the circuit as shown by dotted lines (Refer Figure 2) through patch chords.
2. Select the voltmeter range to 2V, current meter range to 250μA and Load Resistance (RL) to 50Ω.
3. Switch ON the lamp to expose the light on Solar Cell.
4. Set the distance between solar cell and lamp in such a way that current meter shows 250 μA deflections. Note down the observation of voltage and current in Table 1.
5. Vary the load resistance through band switch and note down the current and voltage readings every time in Table 1.
6. Plot a graph between output voltage vs. output current by taking voltage along X-axis and current along Y-axis.

When experiment is performed in Sun Light

1. Connect the circuit as shown by dotted lines (Refer Figure. 2) through patch chords.
2. Select the voltmeter range to 4V, current meter range to 2.5mA and Load Resistance (RL) to 50Ω.
3. Expose the solar cell to sun light.
4. Note down the observation of voltage and current in Table 1.

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5. Vary the load resistance through band switch and note down the current and voltage readings every time in Table 1.
6. Plot a graph between output voltage vs. output current by taking current along X-axis and voltage along Y-axis. You should get a curve similar to shown in Figure 2.

Determining Fill Factor

Draw a rectangle having maximum area under the V-I curve and note the values of V_m and I_m. Note the voltmeter reading for open circuit, V_{OC} and milliammeter reading with zero resistance I_{SC}. Using these values, calculate the fill factor for the cell.

Observations

Voltmeter reading for Open Circuit, V_{OC} = …. Volts

Millimeter reading with Zero Resistance, I_{SC} = . . . mA.

Table 1

S. No.	Voltage	Current	Load Resistance (R_L)
1			
2			
3			
4			
5			

From the Graph

Value of V_m = … volts

Value of I_m = … mA

Maximum useful Power = $V_m \times I_m$ mW

Ideal power $V_{OC} \times I_{OC}$ = … mW

Fill factor = $V_m \times I_m / V_{OC} \times I_{SC}$

Precautions

1. The solar cell should be exposed to sun light before using it in the experiment.
2. Light from the lamp should fall normally on the cell.
3. A resistance in the cell circuit should be introduced so that the current does not exceed the safe operating limit.

EXPERIMENT 20: Determining the Specific Rotation of Sugar Solution.

NOTES

Introduction

Specific rotation [α] is a property of a chiral chemical compound. It can be defined as the relative change in orientation of monochromatic plane-polarized light, per unit distance–concentration product, as the light passes through a sample solution. If a compound of solution is able to rotate the plane of polarization of plane-polarized light, then it is known as 'Optically Active'. Optical rotation is calculated using an instrument called a polarimeter. There exist a linear relationship between the observed rotation and the concentration of optically active compound in solution. Hence specific rotation is measured using either of two equations, depending on whether the sample is a pure chemical to be tested or that chemical dissolved in solution.

Theory

A polarimeter consists of two Nicol prisms which work as polarizer and analyzer as well. These can be rotated about a common axis and the substance, the substance for which the rotation is to be determined, is placed in a tube in between these two Nicol prisms. The half shade plate is placed between the polarizer and the solution tube (Refer Figure 1).

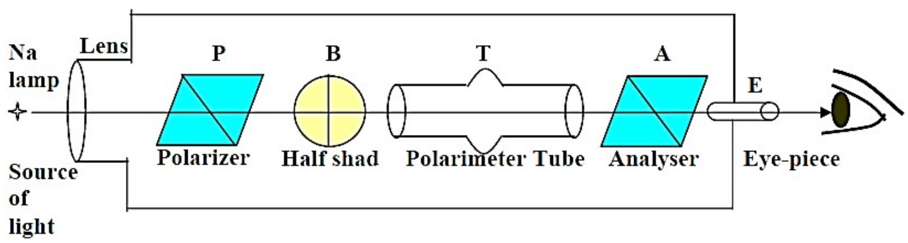


Fig. 1 *Schematic of the Experiment*

This polarizer made up of a circular plate, one half of which is made by cutting quartz plate parallel to the optical axis. The thickness is such that it can produce a retardation of half-a-wavelength of sodium light between the ordinary and extraordinary rays. While the other half of the plate is made by glass having thickness in a manner to transmit the light with same intensity as that coming out from the quartz. Hence finally, there will be two plane polarized beams of light. One which passes through the glass portion and other passes through the quartz. These polarized light beams are of the same intensity are inclined on the principle section of the analyzer will appear equally bright two halves of the field-of-view when observed through the eyepiece. However if we fills the sugar solution tube in between the polarizer and the analyzer, it causes the rotation of the plane of the polarization of incident lights. We estimate this property of the optically active compound by measuring the specific rotation ([α]) which is a property of a chemical compound. It is defined as the change in orientation of monochromatic plane-polarized light, per unit distance concentration product, as the light passes through

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a sample of a compound in the solution. Compounds which rotate light clockwise are said to be dextrorotary, and correspond with positive specific rotation. On contrary, the compounds which rotate light counterclockwise are said to be levorotary, and correspond with negative values of specific rotation. The specific rotation can be estimated as

$$\alpha = \frac{\theta}{l * c}$$

Where (l) is the tube length, and c is the concentration. Here c is defined as the dissolved mass (gm) of the compound per unit volume (cc). A slight rotation in the plane of polarization in the clockwise or anticlockwise direction causes one component greater than the other. Therefore, either the quartz portion appears brighter than the glass or vice-versa. Thus, the analyzer can be set accurately so that the two halves of the field become equally bright.

Aim: To determine the Specific Rotation of a Sugar Solution using a Laurent's Half-Shade Polarimeter.

Apparatus: Polarimeter, Solution Tube Filled with the given Solution.

Procedure

1. Switch on the power of the polarimeter instrument.
2. Illuminate the Sodium Lamp (Yellow Light) at maximum emission. The light will pass through the solution tube.
3. Make an experiment with the distilled water. It will be filled in the tube.
4. Rotate the polarimeter using the rotating nob (see it at the bottom of the circular scale in Figure 1 left-panel). It also rotates the circular scale.
5. First keep the eyepiece focused on the maximum intense yellow strip, and after rotation of the polarizer check the appearance of the intense black-strip at the same place. You will not note the corresponding scales of these two positions. This is just to examine the focus of the eyepiece for the incoming polarized light.
6. Now again keep the eyepiece focused on the position where yellow or black strip was seen with maximum contrast, and then slightly rotate the analyzer. Once the yellow or black strip disappears, i.e., fades against the background and less intense and almost uniform field-of-view appears, note the reading of circular scale as well as Vernier Scale.
7. The polarizer plate consists of equal brightness of two component of polarized light at this point, so the field-of-view appears almost uniform. By slightly rotating it either in clock-wise or anti-clockwise direction, the deviation from this condition will be observed.

Table 1 *Observation Table*

Reading on Analyzer for Equal Illumination in Degrees													Rotation in Degrees	
With distilled water							With sugar solution							
First position			Second position (180° apart)			Strength of the solution per 100 c.c.	First position			Second position (180° apart)			Angle (θ_1)	Angle (θ_2)
Main Scale	Vernier	Total	Main Scale	Vernier	Total		Main Scale	Vernier	Total	Main Scale	Vernier	Total		

Fill the solution tube now with a given concentration of sugar (10 %; 5 %; 2.5 %) and perform the above experiment again and note down the corresponding readings of the circular scale.

8. The Vernier Scale has markings from 0 to 10, however, it has 20 divisions. It resembles with the 20 divisions of the circular scale (in degree). Therefore, the least count of the Vernier Scale is 0.05°. It should be noted that the circular scale ranges from 0° to 180°.
9. The circular scale reading is that how many its divisions already passed from the zeroth of the Vernier scale. Note that reading in the table. While, for the reading of Vernier scale we see the division of this scale which matches exactly with the division of circular scale. We multiply that division of Vernier Scale with its least-count and add in the reading of the main circular scale.
10. θ_1 is the difference between the reading of the first position on the circular scale for the sugar solution to the same for the distilled water. Similarly, θ_2 is the difference between the readings of the second position on the circular scale for the sugar solution to the same for the distilled water.
11. Mean θ_1 is estimated as $\theta_1 + \theta_2/2$, which is the angle of the rotation of the plane of polarization of the light, when it passes through the solution.

Observations

1. Room Temperature = ... °C.
2. Length of the Solution Tube = ... dm.
3. Mass of the Sugar Dissolved = ...gm.
4. Volume of the Solution = ...in c.c.
5. Least Count of the Circular Scale = ...
6. Least Count of the Vernier Scale = ...

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Results

1. The formula to calculate the Specific Rotation (α) is given by,

$$\alpha = \frac{\theta}{l} \times \frac{V}{x}, \quad ...(1)$$

   Where,

   α = Specific Rotation

   l = Length of the Solution Tube in dm

   V = Volume of the Solution in cc

   x = Weight of the Dissolved Sugar in gm

   θ = Rotation in Degrees

2. The Specific Rotation () of the sugar solution (for a given concentration per decimeter) solution at.....°C is ....°.
3. Estimate the same parameter α for the different concentrations of sugar solution.
4. Error estimation as per the general instruction.
5. Draw a graph between rotation vs concentration of the solutions.

Precautions

1. There should be no air-bubble in the tube while filling it with solution or distilled water.
2. While taking one set of the observations, the polarizer should not be disturbed.
3. The cap of the tube should not be tightened beyond a limit as it may strain the glass. Strained glass may produce elliptically polarized light which might interfere with the setting.
4. Two positions at ±90° may appear where the equal illumination remains for a long range. These readings should not be taken.
5. Switch off the lamp after completing the experiment.